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Rio Blanco Oil Shale Company

SCOPE OF WORK
LEASE SUSPENSION PERIOD
ENVIRONMENTAL MONITORING PROGRAM
TRACT C-a OIL SHALE LEASE

January/1983

Gulf Oil Corporation / Standard Oil Company (Indiana)
A General Partnership
2851 South Parker Road, Aurora, Colorado 80014

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REVISION 7.0
JANUARY 1983

SCOPE OF WORK

Rio Blanco Oil Shale Company
Lease Suspension Period
Environmental Monitoring Program
Tract C-a Oil Shale Lease

Gulf Oil Corporation
and
Standard Oil Company (Indiana)
A General Partnership
2851 South Parker Road
Aurora, Colorado 80014

SCOPE OF WORK

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1.0 INTRODUCTION

Rio Blanco Oil Shale Company (RBOSC) has been conducting environmental monitoring studies on Tract C-a since September 30, 1977, when baseline and interim period inventory studies were completed. The monitoring studies have been conducted to assess the impact of oil shale operations on Tract C-a and the vicinity as development progresses. Prior to October 13, 1980 (the date of ignition of the first MIS retort) the development was confined to surface disturbances in a relatively small area (<400 acres) related to construction activities, and dewatering and reinjection. Therefore the data collected between October 1, 1977 and October 13, 1980 are largely indicative of baseline conditions.

Monitoring studies have been conducted in accordance with the program described in the RBOSC Modular Development Phase Environmental Monitoring Program dated May 1977 and approved by the Oil Shale Office (OSO) on August 17, 1977.

An amended version of this program (Revision 5.2) dated March 30, 1979 was approved by the OSO on April 16, 1979 with 17 conditions. Revision 5.2 was to cover the period from January 1979 through December 1981. However, RBOSC modified their development plans and proposed the construction of a surface retort, open pit mine, and associated ancillary facilities and corridors in the spring of 1981. In order to monitor potential impacts of these operations, RBOSC revised the monitoring program again. That program (Revision 6.1) was dated February 25, 1981 and was approved on May 1, 1981.

Revision 6.1 was subsequently modified to reflect deferal of the proposed Lurgi demonstration project and completion of the MIS testing program. These modifications were implemented as soon as feasible after approval by the OSO. A record of all modifications is kept in RBOSC's offices and by the OSO.

Although the MIS demonstration was a success, RBOSC studies have shown that approximately 2.5 times more shale oil can be recovered from Tract C-a by open pit mining and surface retorting compared to the MIS technique. This

open pit development approach assumes that off-tract land is used for process facilities and disposal of overburden and processed shale.

On August 1, 1982 RBOSC was granted a suspension of the Tract C-a lease until off-tract lands for disposal can be obtained. The mine on Tract C-a will be placed in a non-accessible stand-by status and activities on tract reduced to a minimum.

This scope-of-work (Revision 7.0) presents the environmental monitoring program to be conducted during the interim period of lease suspension.

1.1 OBJECTIVES

The Tract C-a lease stipulates that a monitoring program shall be conducted before and during development operations, to provide (1) a record of changes from pre-development environmental conditions; (2) an ongoing check of compliance with lease provisions and applicable federal, state, and local environmental control requirements; (3) timely recognition and notice of any adverse impacts; and (4) a factual basis for revision of lease stipulations and (5) a basis for defining the needs for future monitoring programs. The monitoring program is designed to meet these stipulations as well as to satisfy the specific monitoring requirements requested by the OSO.

In addition to these background and impact-related monitoring objectives, RBOSC is conducting programs to develop reclamation success criteria, wildlife habitat mitigation measures, and to better characterize the smaller scale meteorological nature of process plant and disposal sites. These testing programs address the ecological interrelationships which need to be characterized in order to effectively project environmental impacts and to efficiently implement mitigation procedures for future development.

The environmental monitoring data base compiled since 1974, data collected in special testing and analysis programs, and evaluations of possible impacts of future developments will be used to design monitoring programs appropriate for those development activities. Such evaluations will also be used to provide an assessment of continuing monitoring needs.

1.2 MONITORING PROGRAM DEVELOPMENT

Development of an environmental monitoring program is a dynamic process involving identification of potential impacts, selection of methods to monitor these impacts, compilation and analysis of data, and feedback.

Requisite to the measurement of development-related impacts is a thorough knowledge of pre-development, baseline environmental conditions. For Tract C-a this knowledge was obtained through a two-year baseline study. The results of this study are summarized in the Final Environmental Baseline Report (RBOSP 1977a).

Environmental impacts to be monitored as a part of this program have been selected on the basis of their significance, measurability, and indicator value. This process was thoroughly described in the Final Environmental Baseline Report and Progress Report 10 (RBOSP 1977b). RBOSC environmental specialists have evaluated the measurability of those impacts which were assessed as significant, and have developed programs to monitor these impacts.

Impacts which were assessed as significant, measurable, and having dependable indicator parameters were selected for monitoring. Some exceptions were made for impacts which are sensitive from a public or regulatory standpoint, and for specific monitoring requirements of the OSO and other regulatory agencies. The selected impacts are believed to reflect environmental conditions on Tract C-a and the ajoining project area. Data obtained from the monitoring program will be analyzed and fed back into a re-assessment process to confirm that the objectives of the program are being accomplished. If not, the program will be modified as necessary, in consultation with the OSO. Monitoring methods selected by RBOSC environmental specialists are based on commonly utilized procedures, on data collected during the baseline studies, and on knowledge of the type and format of data required by various agencies.

1.3 MONITORING PROGRAMS

Monitoring and/or evaluation programs have been developed for the following environmental components:

2.0 Air Studies
3.0 Terrestrial Ecology Studies
4.0 Aquatic Ecology Studies
5.0 Hydrology Studies

This scope of work supplies detailed information on specific objectives and the development of techniques designed to accomplish the program objectives. In most cases, these objectives involve the evaluation of changing conditions due either to possible impacts from past tract activities or changes due to off-site activities.

RBOSC has established quality assurance, data management, and reporting procedures as part of the environmental monitoring program. An overall description of these procedures is given in Section 6.0, Quality Assurance, Data Management, and Reporting Procedures. These procedures are applied to each of the programs listed above.

LITERATURE CITED

Rio Blanco Oil Shale Project. 1977a. The Final Environmental Baseline Report. Gulf-Standard, Denver, Colorado.

Rio Blanco Oil Shale Project. 1977b. Progress Report 10. Gulf-Standard, Denver, Colorado.

2.0 AIR STUDIES

Development of the tract may result in various disturbances to the air environment. An intensive effort to quantify any disturbance has been made since RBOSC obtained the lease to Tract C-a. The ambient air quality of the area was measured very intensively before development during the baseline studies (at four sites), on a reduced scale during the interim period (at one site), and was again being measured intensively at three sites during the MIS demonstration program. Recently, the program was reduced from three to two monitoring sites.

The baseline studies showed that, on the average, measurable values of CO, NO, NO_x, H_2S and SO_2 were not present on the tract. Measurable quantities of methane (CH_4), total hydrocarbons (THC), ozone and total suspended particulates were detected on the tract. The average methane concentration was near the global average. Although federal guidelines exist for nonmethane hydrocarbons (NMHC, obtained by subtraction of methane from total hydrocarbons), NMHC concentrations measured were often unreliable due to the inherent errors in the available monitoring techniques. Although the site is located in a pristine area, ozone was often detected during the baseline studies at concentrations approaching the National Ambient Air Quality Standards (NAAQS). In 1978 the NAAQS for ozone was raised by 50 percent, however, which has alleviated this problem. The average particulate concentrations measured during the baseline were fairly low, which is characteristic of a semi-arid region in a remote area. In general, the four baseline stations provided one set of background air quality data and three additional data sets that provided support information.

Since only hydrocarbons and ozone of the gaseous constituents were found in measurable quantities during the baseline studies, most interpretative discussions of air quality in the area have centered around these pollutants. The hydrocarbons are important primarily because they are precursors to photochemical smog. Over 90 percent of the average measured baseline hydrocarbon concentration was methane, the least reactive hydrocarbon. The source of the nonmethane hydrocarbons could not be definitely identified. Potential

sources include natural gas wells in the vicinity and emissions from vegetation such as sagebrush and pinyon-juniper.

Relatively high ozone concentrations, such as found on the tract, are typical of many rural or remote locations. The cause of these elevated ozone concentrations is still subject to debate, and may be due to natural reactions occurring at the site, stratospheric injection, long range transport or some combination of these processes.

The climatology of the area was described in the Final Environmental Baseline Report (RBOSP 1977). Briefly, the climate can be characterized as semi-arid, with hot summers and moderately cold winters. Severe weather is very uncommon in the region. The skies are clear most of the year, and the humidity is generally quite low. The combination of bright sunshine and strong nocturnal radiational cooling leads to large diurnal temperature changes. Thus, valley winds are quite common in the area.

The local climate is important because the tract is intersected by several gulches, resulting in large topographic variations conducive to the development of mountain-valley winds. These local winds can have a significant influence on the dispersion of pollutants in the atmosphere. It has been noted, both in the 1976 tracer test and the monitoring data, that inversions occur frequently in the gulches. As a result, if pollutants enter the gulch system, they will tend to stay there, producing locally high concentrations. Thus, the interactions and coupling between the mesoscale and local winds are very important in determining the ambient air concentrations.

The upper air studies during the baseline period showed that the average mixing height at Site 1 varies from 600 feet above ground level during the fall to 3100 feet above ground level during the summer.

The impact assessment assumed that tract development would have no effect on the meteorological parameters, with the possible exception of the atmospheric water vapor content (measured by relative humidity or dew point). As a result, the primary influence and importance of the meteorology at the tract is in an indirect role by influencing the dispersion of pollutants.

2.1 AMBIENT AIR QUALITY MONITORING

A. Gaseous Constituents

1. Objectives

During the interim period no significant air quality effects are anticipated from the low level of tract activities. However, certain changes may occur as a result of other activities in the region. The purpose of the air quality monitoring program is, therefore, to provide a quantitative basis for evaluating any changes in the ambient constituents. Specific objectives are:

- To measure the ambient levels of specific air quality parameters and to determine long-term trends in the air quality around the tract.
- To provide air quality data which can be compared to the relevant state and federal air quality standards.
- To provide air quality data which allow the implementation of a control/treatment concept in assisting in the evaluation of future tract influences on the ambient air quality.
- To provide a continuous time series of air quality data, which will allow, in conjunction with the meteorological data, analysis of the air quality impact of emissions from future tract operations.
- To provide data which will allow validation and perhaps improvement of the air quality models which have been used to predict the air quality impacts resulting from tract emissions.

2. Methods

Certain air quality gaseous constituents are monitored continually with automated instrumentation. The pollutants being measured were chosen because either tract operations are expected to release these pollutants, because they are necessary to characterize the air quality of the region or because

monitoring is required by the terms of the Tract C-a lease or other environmental regulations. The data are recorded with an automatic digital data acquisition system backed up with strip chart recorders.

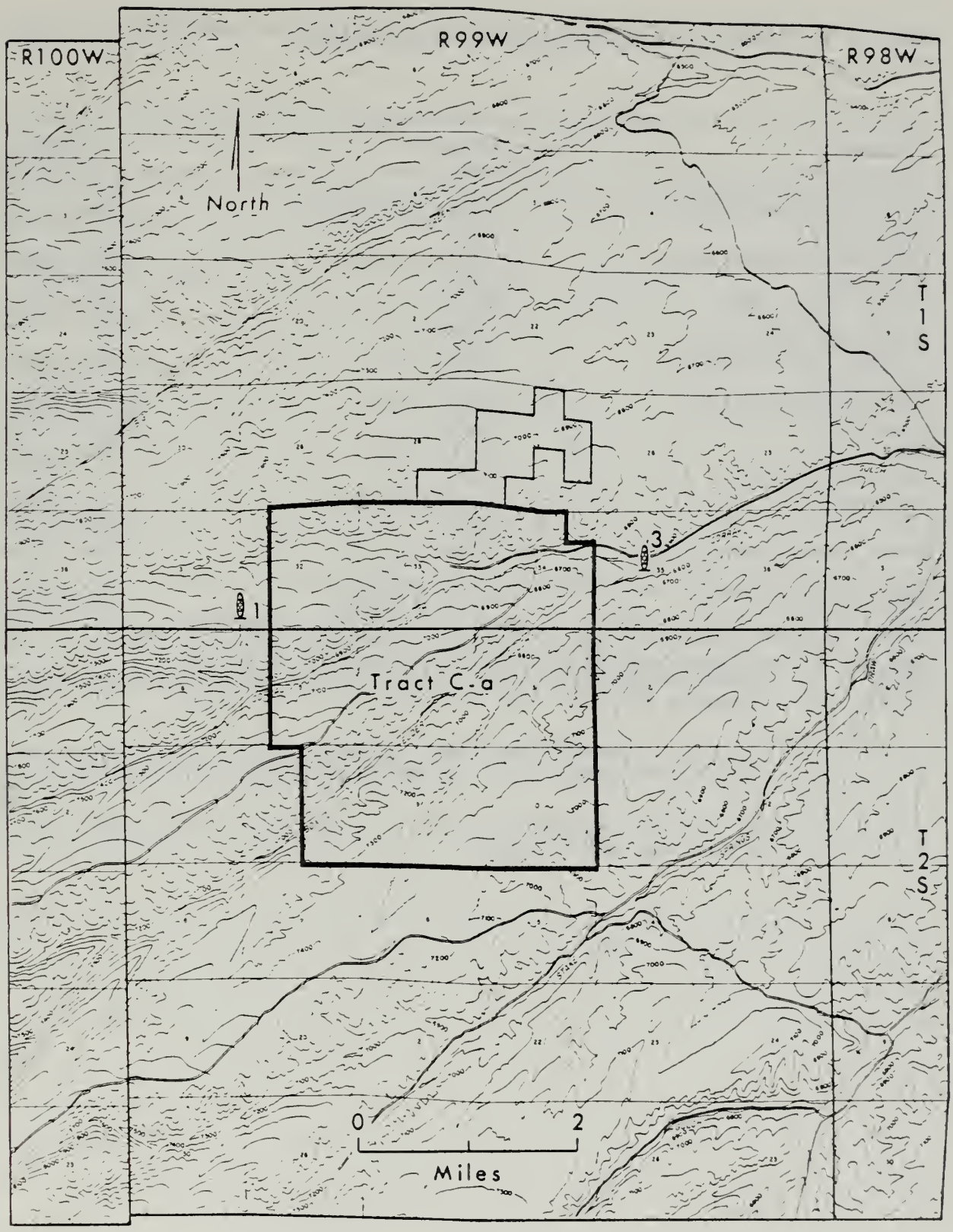
a. Parameters - The air quality parameters monitored in the vicinity of the tract are SO_2, H_2S, CO, NO, NO_x and O_3. Total hydrocarbons and CH_4 were measured at Site 1 until February 1978, when they were discontinued with the approval of the OSO, due to the inaccuracy of the NMHC calculation.

b. Monitoring Locations and Schedule - Figure 2-1 illustrates the monitoring locations proposed for the suspension period. Table 2-1 lists the baseline monitoring schedule, and Table 2-2 lists the current or planned monitoring schedule. Site 1 will continue operation during the suspension period. Site 1, just west of the tract boundary, is the location at which the greatest number of air quality and meteorological parameters have been monitored to date. Continued monitoring at this location for the full complement of air and meteorological parameters will provide continuity with the baseline data set so that changes in the ambient air quality may be detected. In addition to the data set continuity, Site 1 provides a valuable measurement of the ambient air quality of the region (the control site) due to its location, which is generally upwind of the tract development.

Site 3 is located in the approximate center of the drainage valley leading away from the northeast corner of the tract. This site will be used to develop a continuing data base for ambient particulate concentrations near Tract C-a.

c. Monitoring frequency - The onsite instrumentation presently being used for measurement of the gaseous air quality constituents is capable of continuous operation.

When the instruments are serviced and maintained on a regular schedule, data recovery is expected to be near 90 percent on an annual basis. This recovery rate exceeds the federally recommended minimum of 75 percent (EPA 1976). An upgraded automatic data acquisition system has been installed at Site 1. This system automatically scans all parameters 12 times each minute and



Meteorological and Air Quality Monitoring Sites

Figure 2-1. Air Studies Monitoring Sites

Table 2-1. Baseline Air Quality Monitoring Schedule[1]

Parameter	Location	Frequency
Sulfur Dioxide (SO_2)	Sites 1,2[2],3,4[3]	Continuous
Hydrogen Sulfide (H_2S)	Sites 1,2,3,4	Continuous
Nitric Oxide (NO)	Sites 1,3	Continuous
Nitrogen Oxides (NO_x)	Sites 1,3	Continuous
Carbon Monoxide (CO)	Sites 1,3	Continuous
Ozone (O_3)	Sites 1,3	Continuous
Methane (CH_4)	Sites -,2,3,4	Continuous
Total Hydrocarbons (THC)	Sites 1,2,3,4	Continuous
Particulates (TSP)	Sites 1,2,3,4	Every 3rd Day

Note:
1. Baseline monitoring was conducted from February 1975 through January 1977.
2. Site 2 is located near the southwest corner of Tract C-a and was recently used only for meteorological data collection.
3. Site 4 was located about 5 miles downvalley from Site 3 and has since been deactivated

Table 2-2. Proposed Air Quality Monitoring Schedule[1]

Parameter	Location	Frequency
Sulfur Dioxide	Site 1	Continuous
Hydrogen Sulfide	Site 1	Continuous
Nitric Oxide	Site 1	Continuous
Nitrogen Oxides	Site 1	Continuous
Carbon Monoxide	Site 1	Continuous
Ozone	Site 1	Continuous
Particulates	Sites 1,3	Every 4th Day

Note: 1. Monitoring for these parameters began in September 1977 except for particulates monitoring which was initiated in December 1977.

computes 1-hour averages of the meteorological and air quality parameters. These data are stored on magnetic tape. All time designations are in local standard time (Mountain Standard) and the seasons of the year are defined as: Spring - March, April and May; Summer - June, July and August; Fall - September, October and November; and Winter - December, January and February. Data hours are computed from data acquired preceding the hour. For instance, the 0200 data point is the data average from 0100 to 0200 hours. Interim five-minute data averages are computed by the system and recorded on hard copy for future study, if necessary.

d. Instrumentation and data acquisition techniques - The air quality monitoring instruments used at the tract meet the standards of the federal reference methods. Instrumentation is replaced if it gives unsatisfactory performance due to age or general wear. The monitoring system will be upgraded as necessary with state-of-the-art instrumentation if significant advances are made in instrument technology and in response to regulatory requirements.

Two parallel methods are used for data acquisition from the air quality monitoring instruments. In the primary system, the instrument output signal is digitized by the data aquisition system, averaged, and recorded on both magnetic tapes and paper hard copy. In the backup system, the instrument output signal is recorded on a channel of a multipoint strip chart recorder.

e. Data handling and quality assurance procedures - Magnetic tapes and strip chart records are transferred from the site to the Denver headquarters every two weeks. The tapes are logged in by a programmer and the data are printed out in easily readable format, reviewed by an analyst and filed for quarterly batch processing. The strip charts are logged in by a technician and reviewed by an analyst when data are not available from disk or the onsite hard copy. If insufficient data are recovered from the magnetic tape record, data reduction technicians supplement the data set by reducing additional data from the strip charts. Documented work instructions for defining missing data, determining hourly averages, minimum detectable level, etc., are used for manual data reduction. Manually reduced data are punched on cards and merged with the magnetic tape data. The digital system is checked

on a one-hour-per-week basis by comparing the digital values of all parameters with the analog values derived from the strip charts for the same time period.

Operation and maintenance of the air quality instrumentation are performed by site technicians. A station log is maintained in which relevant information is recorded each time the facility is visited. In addition, the technician has a site-specific checklist on which to record instrument performance tests, and a documented work instruction for site surveillance. These records are completed at least once each week. Performance tests require a zero and span check of all instruments. These tests consist of switching the instrument sample line from the ambient air intake manifold to a known gas concentration obtained either from a standard gas cylinder or a permeation tube source that has been standardized. Quality control charts are maintained to record the results of the zero and span tests. Control limits as recommended by EPA quality assurance procedures are established to maintain acceptable instrument performance.

Calibration of the air quality instrumentation is performed at least once each 90-day period. These calibrations, along with the control charts, are used to evaluate instrument accuracy. The calibrations are performed in accordance with documented work instructions by using either permeation tubes or gas cylinders traceable to NBS, per EPA protocol recommendations.

Scale factors for each parameter are established from the nominal span settings of the instruments. Corrections to these scale factors are developed from the internal quarterly calibrations, if analysis of the calibration results show that corrections are necessary.

The final scale factors are applied to the air quality data, which are assembled into a complete and finished data set on a six-month basis. This data set is then combined with the meteorological data and written on a magnetic tape.

The air quality monitoring program includes quarterly independent quality assurance audits. Dynamic gas calibrations are performed with test gases

which are independent of the gas reference cylinders maintained on site for the weekly dynamic tests.

Additional quality assurance will be provided through semi-annual internal audits. These audits include site visits and are designed to insure that both site personnel and technical office personnel are following prescribed procedures as given in this work scope.

3. Experimental Design and Data Analysis

The objective of the air quality monitoring program is to document quantitatively any substantial changes in the air quality around the tract. The data from baseline or other development phases are to be used as a control and tested against data collected during the current period.

Because the air quality monitoring is performed on a continuous basis, the sample sizes will be very large. When possible, each monitored pollutant will be tested as outlined above, by using techniques such as analysis of variance and multiple regression. It is difficult, however, to specify which statistical techniques will be most appropriate to analyze any air quality impacts which may occur in the yet-to-be collected data set. These techniques will be selected from review of suggested analyses described in the literature and EPA publications and after consultation with the OSO.

A major purpose of the air quality data analysis will be to gain a better understanding of the pollutant sources and sinks, and the dynamic interactions affecting pollutant concentrations on the tract. The onsite meteorological data will be used extensively to aid in the air quality analysis. Comparisons will also be made between monitored results, and the federal and state regulatory standards.

B. Particulates

1. Objectives

Suspended particulate matter is of concern on and near the tract because it is subject to federal and state regulations. It is, therefore, extensively monitored in the environmental program. Specific objectives are as follows:

- To provide data which can be compared to the relevant federal and state ambient air quality standards (including proposed new standards for inhalable particulates).

- To provide a data set for comparison during future development activities.

- To attempt to correlate measured particulate loadings with specific sources and with other significant air quality and meteorological parameters.

The concentration of suspended particulate matter on the tract was shown to be low during the baseline studies. A general trend occurs in the data set of very low ambient particulate concentrations during the winter months (due primarily to the snow cover), and higher concentrations during the warm, dry summer.

2. Methods

a. Parameters - Total suspended particulates are measured according to the federal reference method using high volume samplers. In addition, concentrations of particlulates smaller than 10 microns (the expected revision of the federal particulates standard) will be determined by using size-selective inlets on high-volume samplers.

b. Monitoring Locations and Schedule - High volume samplers are operated at Sites 1 and 3 (Figure 2-1) and are located approximately 5 m above ground elevation.

c. Monitoring Frequency - At least one and as many as four Hi-Vol monitors have been in operation since the start of tract development (Tables 2-1 and 2-2). A 24-hour data sample (from 0000 hours to 2400 hours) is taken at each site. Sites 1 and 3 will be monitored every fourth day during the suspension period.

d. Data Acquisition Techniques and Instrumentation - General Metal Works high volume samplers with Sierra flow controllers are used to acquire samples. An electric clock timer controls the on-off cycle of the sampler. Unexposed filters are conditioned and weighed at the air quality laboratory using the EPA reference technique. The balance is standardized with class S weights. Filters are coded and supplied to the field ready for use. Exposed filters are cycled through the same analytical procedure upon their return to the air quality laboratory.

e. Data Handling and Quality Assurance Procedures - The high volume sampler flow rates are calibrated quarterly with a standard orifice calibrator to determine the flow rates to be used to calculate particulate concentration. The standard orifice calibrator is certified annually at EPA's Region VIII laboratory in Denver.

Each exposed filter carries with it a location verifier and flow meter readings taken before and after sampling by the field technician. Weight determinations are maintained in a log in the air quality laboratory and filters are stored for future reference. In accordance with EPA protocol, a minimum of 10 percent of the filters are reconditioned and reweighed as a quality assurance check.

The particulate data are stored on magnetic tapes on a semi-annual basis for future reference.

3. Experimental Design and Data Analysis Procedures

The purpose of the monitoring program is to define and quantify changes in the total suspended particulate matter around the tract.

The annual and seasonal data sets will be analyzed by statistically comparing the geometric means between data sets using analysis of variance techniques. Another important analysis is the comparison of particulate data with onsite meteorological and site activity data, using multiple regression techniques. This allows inferences to be made concerning the sources and causes of high particulate concentrations.

2.2 METEOROLOGICAL MONITORING

A. Objectives

- To develop a data base which can be used for interpretation of observed air quality variations.
- To develop a meteorological data base that can be used in atmospheric dispersion analysis
- To determine if meteorological conditions influencing atmospheric dispersion are similar during the baseline and subsequent time periods

B. Methods

1. Parameters

The following parameters will be measured at Site 1 as a continuation of the baseline data acquisition program:

- 10 m and 60 m wind direction
- 10 m and 60 m wind speed
- 10 m ambient temperature
- 60 m ambient temperature
- 10 m and 60 m temperature differential
- Precipitation
- Solar radiation
- Dew point
- Barometric pressure
- Snow depth and accumulation

2. Monitoring Locations and Schedule

Table 2-3 lists the baseline monitoring schedule. Table 2-4 lists the planned monitoring schedule. The location of Met site 1 is shown on Figure 2-1.

Table 2-3. Baseline Meteorology Studies Monitoring Schedule[1]

Parameter	Location	Frequency
Wind Speed (10 m)	Sites 1,2,3,4	Continuous
Wind Direction (10 m)	Sites 1,2,3,4	Continuous
Wind Speed (30 and 60 m)	Site 1	Continuous
Wind Direction (30 and 60 m)	Site 1	Continuous
Ambient Temperature (10 m)	Sites 1,2,3,4	Continuous
Ambient Temperature (30 and 60 m)	Site 1	Continuous
Temperature Differential (10-60 m)	Site 1	Continuous
Precipitation	Sites 1,2,3,4	By event
Barometric Pressure	Site 1	Weekly
Solar Radiation	Site 1	Continuous
Relative Humidity	Site 1	Continuous
Snow Depth & Accumulation	Sites 1,2,3,4	By event

Note: 1. Baseline monitoring of these parameters from February 1975 through January 1977.

Table 2-4. Proposed Meteorology Monitoring Schedule[1]

Parameter	Location	Frequency
Wind Speed (10 m)	Site 1	Continuous
Wind Direction (10 m)	Site 1	Continuous
Wind Speed (30 and 60 m)	Site 1	Continuous
Wind Direction (30 and 60 m)	Site 1	Continuous
Ambient Temperature (10 and 60 m)	Site 1	Continuous
Temperature Differential (10-60 m)	Site 1	Continuous
Precipitation	Site 1	By event
Barometric Pressure	Site 1	Weekly
Solar Radiation	Site 1	Continuous
Relative Humidity	Site 1	Continuous
Snow Depth & Accumulation	Site 1	By event

Note: 1. Monitoring was initiated in February 1975 at this station for these parameters.

Site 1, equipped with a 60 m tower, is the most heavily instrumented site. Eleven parameters are currently being measured there. The location of Site 1 is unchanged from the baseline studies and thus allows temporal data analysis. The primary use of the meteorological data will be in the interpretation of the air quality data. Consequently, the meteorological data are collected at the same location as the air quality data. In addition, the meteorological data will be useful in evaluating the Hi-Vol data.

3. Monitoring Frequency

Meteorological parameters are monitored continuously by the automatic digital data acquisition system, backed up by the strip chart recorders. The data acquisition system scans each parameter 12 times each minute and computes an average every five-minutes, which is recorded on hard copy for future reference. Hourly averages are computed from the five-minute averages and recorded on magnetic tape in a similar manner to the calculation of the air quality data.

4. Data Collection Techniques and Instrumentation

The present meteorological sensors for wind speed and direction have performance specifications which meet or exceed the stringent requirements of the Nuclear Regulatory Commission (NRC) Regulatory Guide 1.23 (NRC 1972). To maintain these specifications, these sensors are replaced semi-annually with identical units calibrated by the manufacturer, which are traceable to the National Bureau of Standards.

The temperature sensors are platinum resistance elements that have specifications which meet or exceed the requirements of NRC Regulatory Guide 1.23. To maintain the accuracy of the temperature system, the system is calibrated semi-annually against a certified mercury thermometer in absolute and differential temperature baths.

The dew point measurement instrument is factory calibrated to an accuracy which exceeds the requirements of NRC Regulatory Guide 1.23. The accuracy of the dew point sensor is maintained by proper servicing in the field.

The Belfort weighing bucket recording precipitation gage is calibrated semi-annually by adding precisely measured volumes of distilled water and checking the instrument response. The accuracy is maintained by keeping the collector clean, and by keeping the mechanical mechanisms clean and free of insect intrusion. The wedge precipitation gages, which is permanently calibrated at the factory, is periodically checked to insure that it is clean and its exposure is satisfactory.

The solar radiation sensor is recalibrated at the factory annually. The accuracy is maintained by keeping the collector clean and the field of view unobstructed.

The recording devices are voltage operated and are calibrated with certified test equipment by applying a series of test voltages that permit the determination of sensitivity and linearity.

The geographic azimuth accuracy of the wind direction sensors is established with sighting telescopes using surveyed landmarks. Notes on new snowfall are also recorded.

5. Data Handling and Quality Assurance Techniques

The meteorological data are recorded on magnetic tapes at the site concurrently with the air quality data. The tapes are returned to the data center for computer listing, scaling and data fill-in from strip chart reduction, when required. The new data are reviewed for reasonableness prior to processing.

One hour of randomly chosen analog meteorological data is reduced every other week and compared with the data from the automatic digital system as a check to insure that the digital system is functioning properly.

Copies of the calibration data are forwarded to the analyst responsible for the monitoring system, where they are reviewed. If the review indicates that the data are in need of correction, this is done at that time. The data are

then printed out in a final listing semi-annually and reviewed for reasonableness. Permanent storage of the data is on magnetic tape.

C. Experimental Design and Data Analysis Procedures

The principal utility of site meteorological data is its application in interpreting observed changes in air quality. However, the data set is also useful in determining average meterological conditions and in developing a climatology of the area.

Selected analyses will be performed on the data:

- o Annual and seasonal wind roses for each sensor at each location.
- o Annual and seasonal maximum, minimum and mean values.
- o Monthly, seasonal, annual and event precipitation totals.
- o Frequency of occurrence of stability class derived from ΔT data
- o Joint frequency distribution of wind speed and direction by stability class on an annual basis

These statistics will be compared with earlier periods to determine if the data sets are similar.

Because the meteorological data system is designed to meet the stringent NRC Regulatory Guide 1.23 requirements, it will generally exceed the requirements of the EPA for monitoring data. The collected data should serve as a vital data set for use in dispersion analyses, and for use in special studies of the air quality data.

2.3 SPECIAL STUDIES

The objective of this section is to discuss techniques that go beyond the traditional air quality measurements to better characterize and understand the transport and dispersion of air pollutants in the area around the tract. The primary emphasis at this point will be to understand the local meteorology and its influence on the dispersion of tract emissions. In addition to meteorological studies, RBOSC will cooperate with DOE, EPA or industry organizations in the design of an acid deposition monitoring program, should one be developed. A literature review will also be conducted on fugitive dust emissions from open pit mines with special emphasis on modeling these emissions and impacts.

A. Visibility

The Clean Air Act, as amended in 1977, declared that the prevention of visibility impairment from manmade air pollution is a national goal in mandatory federal PSD Class I air quality areas. Although the oil shale tracts are Class II areas, a mandatory Class I area, the Flat Tops Wilderness Area, is 80 km east of the tract. Changes in visibility may, therefore, be a concern.

Visibility measurements were made during the baseline by using densitometers to determine the visual range on photographic exposures of identified geographical locations at a number of known distances from the camera. Measurements were taken over a period of two years. In general, visibility at the site was excellent, but there was a high variability on both a daily and seasonal basis. The greatest seasonal difference in mean visual range was between the Spring and Fall seasons, with the latter having the greater range. Therefore, when the visibility program was continued after tract development began, the measurements were taken in the Spring and Fall of each year. Due to the large seasonal and diurnal variation, the number of samples required to obtain a representative sample is relatively high.

1. Objective

To provide measurements of visibility such that trends in the data can be distinguished from seasonal or diurnal fluctuations.

2. Methods

The program has included photometric techniques and telephotometers in a cooperative program with Tract C-b during 1978-1982. It is anticipated that the cooperative program with Tract C-b will be continued. Basin-wide visibility is examined during the spring and fall. Photometric methods are described in MDP Monitoring Report 1 (1978). Visual range data is collected using a telephotometer. Data are collected approximately every fourth day during the surveys until a total of 10 days of data are collected.

B. Short-Term Studies

The complex local wind flow patterns associated with rough terrain, such as found in the vicinity of Tract C-a, are not well understood. Because these flows can have a strong influence on the dispersion of emissions from a source, accurately predicting the air quality impacts in complex terrain is a difficult task.

Consequently, RBOSC will cooperate with DOE, EPA or other agencies in conducting short-term intensive experiments in the immediate vicinity of Tract C-a to improve our understanding of the local meteorology and its relationship to the general mesoscale circulation. The overall objective of these studies is to improve our ability to predict the dispersion of emissions from Tract C-a, and to evaluate the adequacy of current air quality models.

Although RBOSC has several years of very complete surface meteorological records, an important area which needs further investigation is the interaction between the surface and upper air wind flows - the coupling of the winds in complex terrain. The problem in studies of this type is that by their nature they are short-term, intensive investigations and must be carefully planned and executed to collect valid and representative data.

Consequently, in order for such a study to be effective, RBOSC will require involvement in the planning stages from both the OSO and EPA. The most

effective approach would be a joint study, with assistance from OSO and EPA personnel in both the planning and execution stages.

Potential studies include smoke releases and tethersonde and airsonde measurements using a small mobile laboratory. This type of instrumentation has found wide acceptance and use in studying the meteorology of complex terrain (Barr et. al., 1980; Orgill et. al., 1980; Whiteman and McKee, 1978; Whiteman and McKee, 1979). Measurements would be appropriate at several locations around Tract C-a, including the MIS process site, possible surface retort processing site (and the surrounding area), Corral Gulch, and 84-Mesa. Experiments may include both nocturnal drainage conditions and daytime convective conditions. The representativeness of the short-term studies may be estimated by taking measurements during each season.

Data analysis of tethersonde and airsonde measurements should greatly improve our understanding of the coupling between the surface and upper air flows, as well as the existence and extent of shear layers in the boundary flow regime. Photographic documentation of the smoke releases improve our qualitative understanding of trajectory flows and dispersion patterns from selected point sources.

The results of these studies would be used for the following purposes:

- To provide data to help evaluate the adequacy of the air quality dispersion models that have been used at Tract C-a.

- To provide data that can be used, in conjunction with EPA's efforts to develop better air quality models appropriate to the area's complex terrain.

- To assist in locating and addressing the adequacy of the ambient air monitoring sites.

- To provide assistance in future plant siting decisions by suggesting favored areas of maximum local dispersion and problem areas of poor potential dispersion capability.

RBOSC is cooperationg in 1982 with an exploratory field program conducted by several national laboratories under DOE/ASCOT (Atmospheric Studies in Complex Terrain) sponsorship. Although the major focus of the experimental work is in the Roan Creek area, one of the labs (NOAA: Atmospheric Turbulence and Diffusion Laboratory) has agreed to take tethersonde and airsonde measurments during the program at Site 3 and the possible plant-site located north of Tract C-a (to study localized flows), and at Site 2 (to study regional flows). These measurements should greatly improve our understanding of the boundary layer meterology in the area, and can be used as a basis to plan further refined studies and to improve site specific air quality modeling.

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3.0 TERRESTRIAL ECOLOGY STUDIES

The RBOSC MDP terrestrial monitoring program is based on the results of the intensive two-year baseline program conducted between 1974 and 1976, a detailed assessment of the terrestrial impacts potentially resulting from oil shale development on Tract C-a and studies conducted since the baseline period. The terrestrial baseline program was conducted on Tract C-a and the area within five miles of the tract boundary and included detailed soils, vegetation and wildlife studies. A complete discussion of the results and interpretation of the terrestrial baseline program is presented in the Final Environmental Baseline Report (RBOSP 1977). Subsequent monitoring studies have completed the characterization of the Tract C-a terrestrial system.

The terrestrial ecology monitoring program for the interim period focuses on specific ecological interactions. The goal of these studies is to assist in the design of measures for restoration of habitats for wildlife and livestock use and mitigation of development impacts. These studies include evaluation of mule deer winter habitat, revegetation success and habitat reconstruction/manipulation (Table 3-1).

Table 3-1. Interim Terrestrial Studies Monitoring Schedule

Study	Location	Studies Initiated	Sampling Frequency
Biotic Monitoring			
Mule Deer - Density	Tract C-a and 3-mile perimeter	Sept. 1977	Annual
Mule Deer - Habitat Evaluation, Browse Use	Two Selected Study Areas	1983	Annual
Mule Deer - Road Kill	County Road 24	Feb. 1977	Daily (Oct.-Apr.)
Threatened and Endangered Species	Opportunistic Observations in C-a vicinity	1974	-
Reclamation Success (MLRB)	Reseeded Areas	1978	Annual
Special Studies			
Experimental Revegetation - Cover Estimates Moisture Monitoring	Plots R1, R2, R3	1975, 1976	Annual for cover, Monthly (April-October) for Moisture
Habitat Studies - Bench Test - Brush Chopping - Reseeded burn area	Test Plots		See Study Plans

3.1 BIOTIC MONITORING

A. Mule Deer Density

Mule deer are the most important game species in Colorado in terms of recreational use and money expended by hunters. The Piceance Creek basin mule deer herd is one of the largest migratory mule deer herds in North America. Tract C-a is within Colorado Division of Wildlife's (CDOW) Game Management Unit 22 (Piceance).

Moderate numbers of mule deer occur on Tract C-a during migration periods, particularly spring, and during mild winters. At other times mule deer are relatively uncommon on the tract. Consideration of the possible effects of Tract C-a oil shale development on mule deer is an integral part of RBOSC's Fish and Wildlife Management Plan.

1. Objectives - Weather is the prime factor affecting mule deer populations. Severe winter conditions result in massive population decline with recovery historically taking several years. Estimates of deer density in a 9 x 9 mile area around Tract C-a will be used to address the following issues: Taking into account the influence of weather, what is the use by deer populations of lands potentially made unavailable by development (of a mine, plant site and disposal) relative to adjacent unaffected areas? Will such "unavailable" lands be reasonably expected to affect the area deer herd?

In addition, a special study will be conducted to the east of the tract to identify factors (vegetation, slope, aspect, nearness to water, etc.) which may influence deer use. This information, gathered in cooperation with the DOW and OSO, will be used to design mitigation programs for future development.

2. Methods - Tract C-a is in the center of a 9x9 mile (81 sq mi) study area which is divided into 9 blocks (3 x 3 miles or 9 sq mi each). Seven quarter sections (160 acres, 64 ha) have been randomly selected from each block.

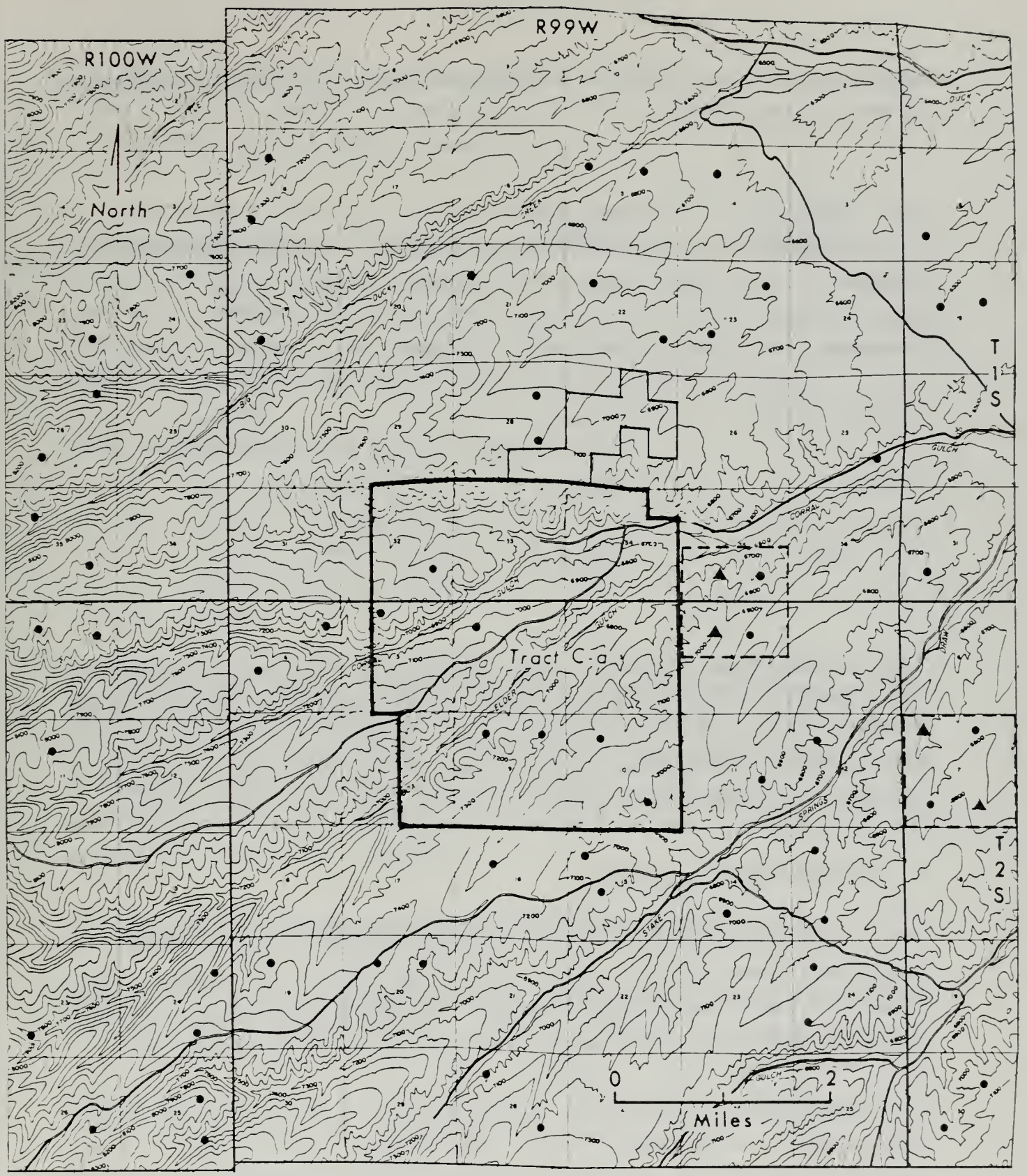
Twenty plots or 2 transects of 10 plots each (107.64 sq ft (1/1000 ha) each) are randomly spaced within each of 63 randomly selected quarter section sampling units (7 units in each of the 9 blocks). The boundary of each plot is determined by placing one end of a 5.8 foot (1.78 m) long chain on a center stake and walking around the stake with the opposite end of the chain pulled taut. Pellet-groups found within the circular plots are counted; to qualify as a group, 20 or more pellets must be present. Groups on the boundary of a plot are counted if one-half or more of the total number of pellets are within the plot. Sampling plots used during monitoring are marked with a numbered metal stake at the center of each plot.

Pellet-group counts are made annually to determine the number of pellet groups deposited during the previous year (Table 3-1). All pellet groups are removed from the plots as they are counted.

In addition, pellet group densities at two selected sample units will be more intensly sampled by doubling the number of transects (Figure 3-1). A program mutually acceptable to OSO and RBOSC for sampling browse in these and possibly other selected areas will be initiated in 1983 to study deer/habitat.

c. Experimental design and data analysis - Assessments of potential impacts of development require knowledge of deer distribution and abundance before mining or enhancement activities begin. A stratified random sampling program (Cochran 1963) is employed to estimate mule deer density from pellet group counts. For each 9 square mile block, 7 of the 36 quarter square-mile sample units were randomly selected then subsampled by two transects, one quarter mile apart, each containing 10 plots, 107.64 ft^2 (1/1000 hectare) in size, spaced at 0.05 mile intervals south to north. The principal reasons for stratification are outlined by Cochran (1963).

Mule deer density estimates are calculated from pellet-group data. The number of pellet groups per unit area, days of use by deer, and deer per acre in the study area are determined as described by Overton (1971). These analyses provide an estimate of the number of deer per square mile in the 81 sq mi study area.



• Mule Deer Pellet Group Sample Unit

[ ] Deer Habitat Intensive Study Sites

▲ Additional Pellet Group Sample Units

Figure 3-1. Mule Deer Monitoring Sites

Differences in deer densities between blocks and over time will be compared by the following ANOVA.

Source of Variation	Degrees of Freedom	F-Ratio	Expected Mean Squares
A. Year	a-1	A/D	$\sigma^2 + \frac{\Sigma\beta_{ij}^2}{a-1}$
B. Blocks	b-1	B/D	$\sigma^2 + \frac{\Sigma\alpha_{ij}^2}{b-1}$
C. Year x Block	(a-1)(b-1)	C/D	$\sigma^2 + \frac{\Sigma\alpha\beta_{ij}^2}{(a-1)(b-2)}$
D. Error	ab(n-1)		σ^2
TOTAL	abn-1		

This two-way, Model I ANOVA is used to determine differences between years (main effect A), and differences among blocks (main effect B) which might indicate differences in deer distribution. If significant differences in the year and block interaction occur, a Duncan's multiple range test will be conducted to determine the sources of variation on the main effect terms.

B. Mule Deer Road Kill Study

The Piceance Creek Basin is currently a center of oil shale and natural gas energy development activity. This activity has resulted in increased traffic flows across mule deer migration routes. The CDOW is interested in obtaining data onthe mortality of mule deer as a result of deer-vehicle collisions.

1. Objectives - The objective of this program is to provide data on mule deer mortality along County Road 24 from Piceance Creek to Tract C-a for compilation and use by the CDOW. These data will be compared to the level of activity on Tract C-a.

2. Method - Mule deer mortality data are collected five times per week, along a 13-mile stretch of County Road 24 from Piceance Creek to Tract C-a during prime migration periods (October to April).

At the initial observance of a new carcass the location is marked on a map using a number representing the sequential kill count of the season (e.g. 4 meaning the 4th new carcass sighted that season). Duplication of counts is avoided by conspicuously marking the carcass with plastic flagging. Marked carcasses are omitted from subsequent counts. Kill counts plus supplementary data are forwarded to the CDOW (through the OSO) on a monthly basis.

Data recorded for each new carcass sighted include:

- Date of observation
- Location (marked on map)
- Sex (male, female, undetermined)
- Age Group (adult, immature)
- Comments

3. Experimental Design and Data Analysis - The program is designed to provide supplemental information to RBOSC for evaluation of effects of traffic related to development on the mule deer herd and to assist the CDOW in compiling regional information on mule deer in the basin. The data are reported in semi-annual reports, but no attempt is made to quantify the data nor to test a stated null hypothesis.

C. Threatened and Endangered Species and General Wildlife Survey

Baseline and interim monitoring studies indicated that Tract C-a does not provide critical habitat for any state or federally endangered species. During baseline studies, incidental sightings of one whooping crane with greater sandhill cranes and one peregrine falcon occurred. These individuals were apparently migrating in the vicinity of Tract C-a.

RBOSC field biologists conduct studies on and near Tract C-a during all parts of the year. Observations of any threatened or endangered species will be

reported to the OSO and appropriate studies will be initiated as determined by RBOSC and the OSO.

D. Reclamation Success

Reseeded areas on and around Tract C-a will be monitored as required by the Colorado Mine Land Reclamation Board. This monitoring will provide an assessment of reclamation success and will be summarized in the annual report to the MLRB.

3.2 SPECIAL STUDIES

A. Experimental Revegetation

1. Objectives

Three experimental sites on Tract C-a were designed to develop revegetation techniques related to surface disturbance and to evaluate use of an artificial soil profile for revegetation of processed shale disposal sites (Figure 3-2). Two sites, established in 1975, address species adaptability, mulch type, timing of fertilizer application, and slope aspect variables as they pertain to revegetation of disturbed areas on Tract C-a. The third site, established in 1976, is monitored to assess the effects of seeding rate, mulch type, and establishment of an reconstructed soil profile on revegetation of Tosco II processed shale.

2. Methods

Coverage of grass, forb, and shrub species is estimated each year on the three experimental revegetation plots. Treatment plots and permanent sampling locations within plots are identified with rebar stakes placed in the upper right hand corners of the plots and/or sampling locations. Aluminum tags attached to these stakes identify the plot number and treatment combination.

Coverage of planted and invaded species is estimated within a sampling frame (1 m^2) placed adjacent to the permanent marking stakes. Sampling frames are subdivided into five percent divisions to aid in these visual estimates.

Soil moisture will be estimated monthly during the growing season at each treatment plot in R_3. Estimates are made by inserting a Troxler® neutron soil moisture probe into permanently placed aluminum tubes. Estimates are used to determine, quantitatively, moisture in the root growth zone as well as other portions of the reconstructed soil profile in the plot.

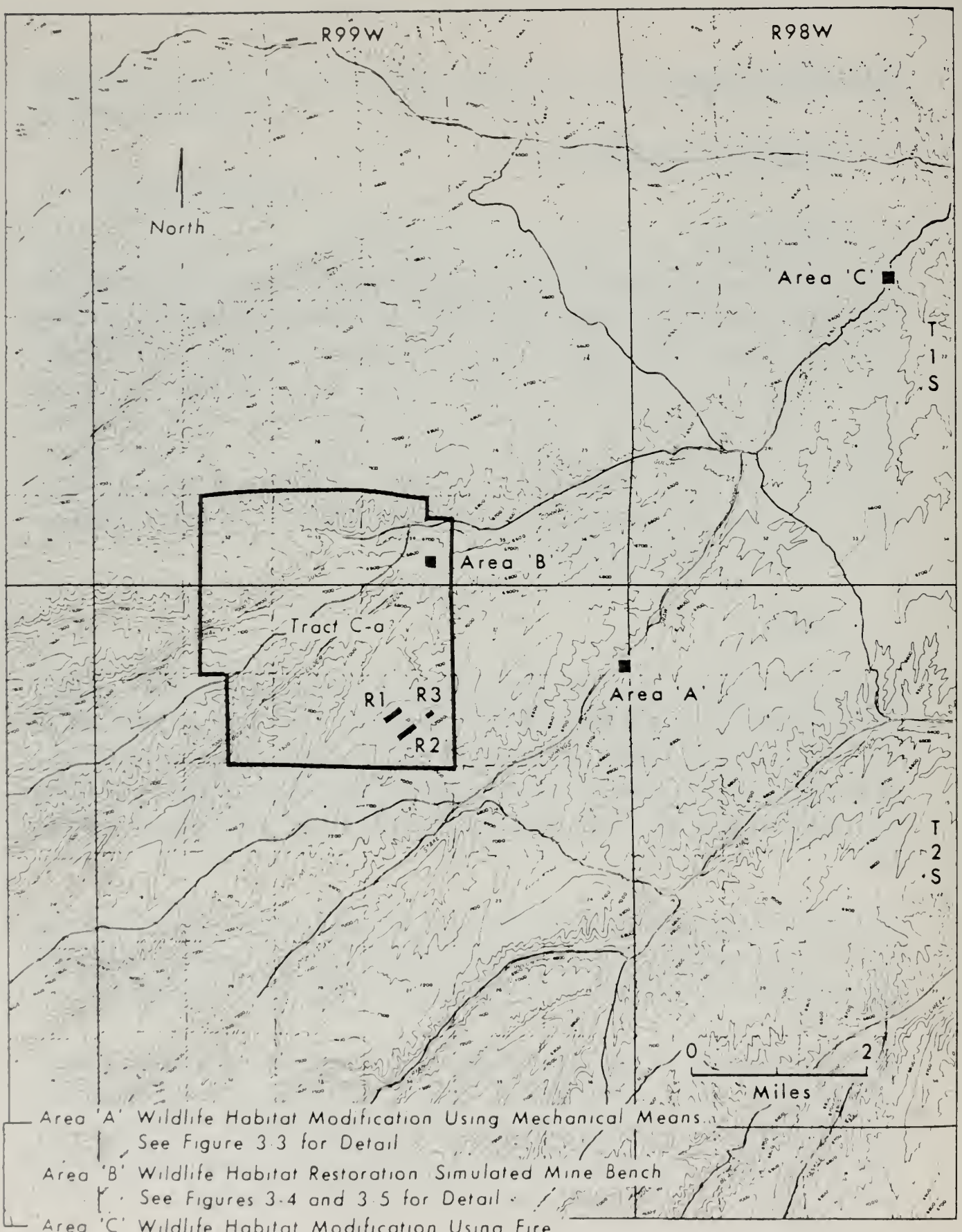


Figure 3-2. Terrestrial Ecology Special Study Sites

3. Experimental Design and Data Analysis

Data collected from sites established in 1975 (Plots R_1 and R_2) are used to test the following hypothesis by plant growth form:

H_o: There is no significant difference in cover or biomass for:

1. planted and/or invaded species
2. four mulch treatments
3. four fertilizer treatments

Data from plots R_1 and R_2 are analyzed by the following Three-Way Model I ANOVA to compare cover.

Source of Variation		Degrees of Freedom	F-Ratio
A	Block a=3	a-1= 2	A/H
B	Mulching b=4	b-1= 3	B/H
C	Fertilizer c=4	c-1= 3	C/H
D	A x B	(a-1)(b-1)= 6	D/H
E	A x C	(a-1)(c-1)= 6	E/H
F	B x C	(b-1)(c-1)= 9	F/H
G	A x B x C	(a-1)(b-1)(c-1)= 18	G/H
H	Error (n=3)	abc(n-1)= 96	
		nabc-1 = 143	

The study initiated in 1976 (Plot R_3) is designed to test the following hypothesis by individual species and collectively by growth form:

H_o: There is no significant difference in cover of planted or invaded species based on:

1. substrate type
2. seeding level
3. mulch type

Data from Plot R_3 are analyzed by the following Three-way Model I ANOVA to compare cover through time.

Source of Variation		Degrees of Freedom	F-Ratio
A	Soil type a=2	a-1= 1	A/H
B	Seeding level b=3	b-1= 2	B/H
C	Mulch c=3	c-1= 2	C/H
D	Seeding level x Substrate type	(a-1)(b-1)= 2	D/H
E	Mulch x Substrate type	(a-1)(c-1)= 2	E/H
F	Mulch x Seeding level	(b-1)(c-1)= 4	F/H
G	Mulch x Seeding level x Substrate type	(a-1)(b-1)(c-1)= 4	G/H
H	Error (n=6)	abc(n=1)= 90	
	Total	abcn-1=107	

B. Mule Deer Habitat Modification Study

1. Objectives

During RBOSC's commercial operation, disturbances of the land will result in the loss of forage for wildlife, primarily mule deer. One means of mitigating these losses is to increase the mule deer carrying capacity of undisturbed areas to maintain the overall carrying capacity. RBOSC initiated an experiment in 1980 to determine the feasibility of producing such increases in carrying capacity using the habitat modification techniques described below.

2. Methods

The critical factor which currently limits mule deer populations in the Piceance Creek Basin is the availability of suitable food during periods of heavy snow cover. Thus, a program designed to increase the carrying capacity of local habitats for mule deer should be aimed at increasing suitable forage as well as providing access for mule deer to these modified areas during periods of heavy snow cover. Habitat modification in large, continuous blocks increases wildlife forage, but such large areas commonly fill with snow during periods of heavy snowfall making the area inaccessible to deer. The RBOSC habitat modification program evaluates a method to avoid this

problem by modifying vegetation in strips, leaving the vegetation between strips undisturbed. The undisturbed strips provide cover and access routes to the modified areas.

The habitat modification experiment was established in October 1980 in the SE¼, SE¼ of Section 1, T2S, R99W in Stake Springs Draw (Figure 3-2). This area includes a valley bottom with dense, uniform sagebrush; a south-facing slope offering several browse species palatable to mule deer; and a travel lane between the bedding area and feeding area, and a north-facing slope characterized by desirable forage species. The experiment was designed to evaluate the effects of several factors critical to increasing deer carrying capacity: (1) snow depth, (2) selective brush removal, (3) quality forage, and (4) fertilization.

To increase desirable forage production, it was necessary to remove the rank sagebrush, in order to reduce plant competition. To do this, two Marden Model L-7 roto-choppers (filled with water for additional weight) were pulled behind a John Deer 450 dozer. Four 5-m corridors were chopped in each of two treatment areas within the valley bottom (Figure 3-3). The corridors in the treatment area adjacent to the south-facing slope were oriented perpendicular to the draw and the direction of most winter winds (NW-SE). Corridors in the treatment area adjacent to the north-facing slope were aligned parallel to the direction of most winter winds (NE-SW). A differential accumulation of snow should occur between the two areas, thereby enabling an evaluation of the effects of such accumulation on forage production and utilization as well as deer movement.

Half of each treatment area parallel to the corridors was seeded, as shown in Figure 3-3. The treated corridors and the untreated sagebrush zones between them were broadcast seeded with the seed mixture in proportions as illustrated on Table 3-2. Half of each treatment area perpendicular to the corridors was fertilized with ammonium nitrate (33.4% nitrogen) at 120 pounds per acre, in the spring of 1981. Both the chopped corridors and the undisturbed sagebrush between them were fertilized.

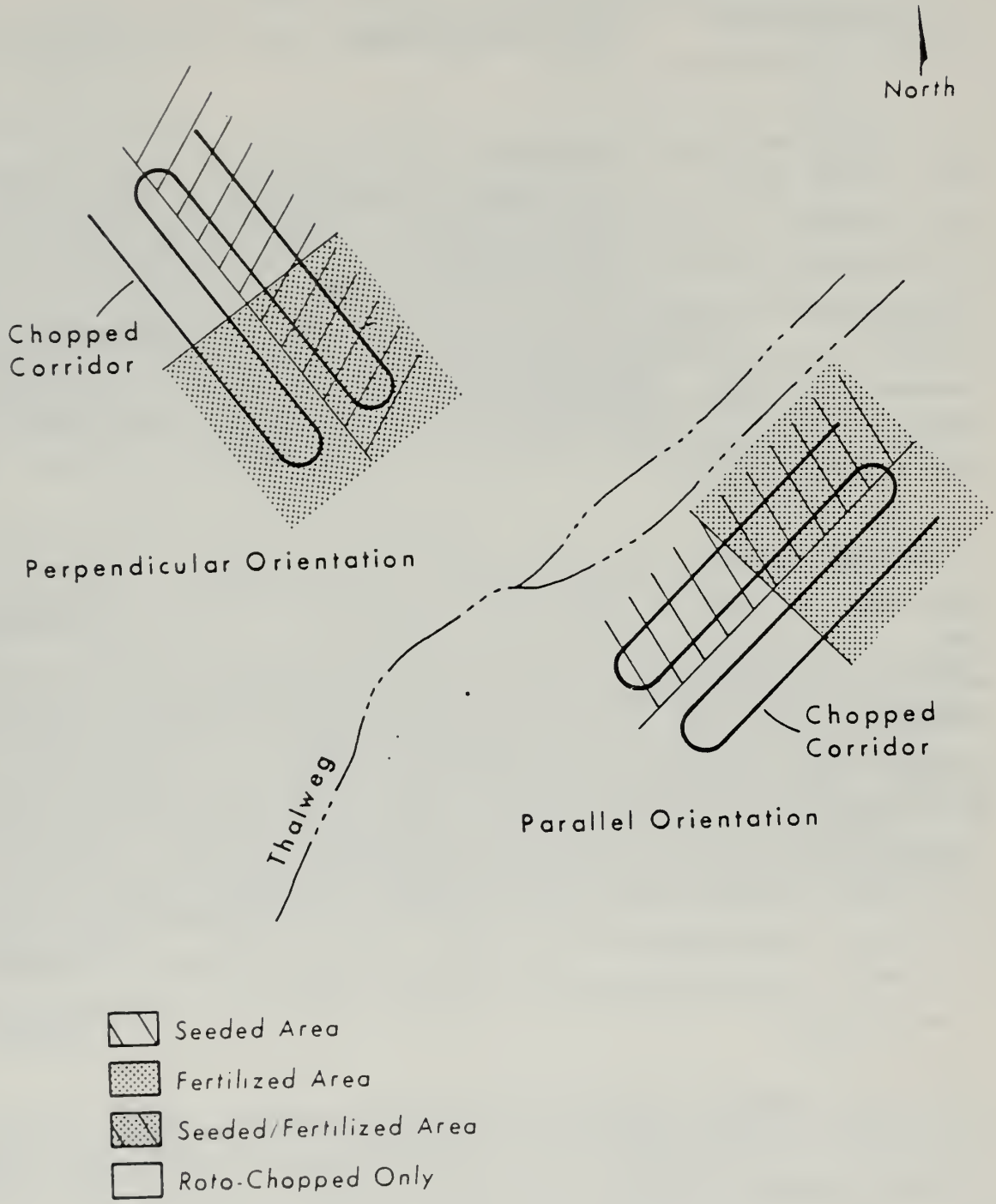


Figure 3-3. Configuration of Seeding & Fertilizing Treatments in Deer Mitigation Study

Table 3-2. Plant Species Broadcast Seeded in the Roto-Chop Experiment Area in Stake Springs Draw

Species	Kg/Ha
Grasses	
Crested wheatgrass (*Agropyron cristatum*)	2.4
Pubescent wheatgrass (*Agropyron trichophorum*)	1.2
Western wheatgrass (*Agropyron smithii*)	3.6
Indian ricegrass (*Oryzopsis hymenoides*)	1.2
Russian wildrye (*Elymus junceus*)	6.0
Subtotal	14.4
Forbs	
Alfalfa (*Medicago sativa*)	3.6
Cicer milkvetch (*Astragalus cicer*)	1.2
Subtotal	4.8
Shrubs	
Four-wing saltbush (*Atriplex canescens*)	2.4
Winterfat (*Ceratoides lanata*)	2.4
Subtotal	4.8
TOTAL	24

The treatment regimes which were established are as follows:

- o chopped
- o chopped and seeded
- o chopped, seeded, and fertilized
- o chopped and fertilized
- o unchopped
- o unchopped and seeded
- o unchopped, seeded, and fertilized
- o unchopped and fertilized

Control areas were also established in undisturbed sagebrush adjacent to each of the treatment areas.

Twelve permanent vegetation transects were established (four in each treated area and two in each control area). Density of shrub species, percent cover of shrub species, and percent cover of each herbaceous species were estimated within eight one-meter square plots on each transect. These parameters are estimated at the end of each subsequent growing season.

3. Experimental Design and Data Analysis

Cover data collected in each of the treatment regimes is analyzed using analysis of variance and t-test techniques the following hypotheses are tested:

Ho: There is no significant difference between cover for the two corridor orientations

Ho: There is no significant difference between cover estimates for:

1. fertilizer rates
2. seeding rates
3. chopped and unchopped areas

The variation in plant cover between the corridor orientations is tested using a student t-test. If a difference between the orientation treatment is significant, a by-variable is used in the algorithm to examine the second null hypothesis for the treatment regimes listed above.

If orientation is determined to be significant contribution to change in cover estimates, the second null hypothesis listed above is examined by growth form and by orientation. A fixed effects (Model I) Three-way Analysis of variance techique is used to examine these treatments. Each of the treatments has unequal subclasses of replication.

The design for this ANOVA is:

Source	df	F-Test	Expected MS. (Model 1)
A. Fertilizer	a-1	A/F	$\sigma^2 + \frac{bc}{a-1}\sum^{a}\alpha^2$
B. Seeding	b-1	B/E	$\sigma^2 + \frac{ac}{b-1}\sum^{b}\beta^2$
C. Chopping	c-1	C/D	$\sigma^2 + \frac{ab}{c-1}\sum^{c}\Upsilon^2$
D. Fertilizer x Seeding	(a-1)(b-1)	D/G	$\sigma^2 + \frac{c}{(a-1)(b-1)}\sum^{ab}(\alpha\beta)^2$
E. Fertilizer x Chopping	(a-1)(c-1)	E/G	$\sigma^2 + \frac{c}{(a-1)(c-1)}\sum^{ac}(\alpha\beta)^2$
F. Seeding x Chopping	(b-1)(c-1)	F/G	$\sigma^2 + \frac{a}{(b-1)(c-1)}\sum^{bc}(\beta\Upsilon)^2$
G. Fertilizer x Seeding x Chopping	(a-1)(b-1)(c-1)	G/H	$\sigma^2 + \frac{1}{(a-1)(b-1)(c-1)}\sum^{abc}(\alpha\Upsilon)^2$
H. Error Term	abc(n-1)		σ^2
Total	abcn-1		

C. Shrub Growth Enhancement on a Simulated Mine Site and/or Disposal Pile Bench

1. Objectives

Reclamation of areas disturbed by Tract C-a activities will be accomplished according to a state and federally approved reclamation plan. Reclamation techniques implemented by RBOSC are expected to result in adequate habitat for livestock and wildlife. However, any additional steps which might reduce the amount of time necessary to establish such habitat are desirable. Shrub growth enhancement through water harvesting techniques is an example of such a step.

In the semiarid environment of the Piceance Basin, increased shrub growth may be achieved by augmenting soil moisture via water harvesting techniques. Water harvesting is a technique designed to conserve and more efficiently utilize normal runoff by concentrating runoff from a large area into a smaller area.

To reduce the potential for soil erosion, benches will probably be required on large slopes resulting from Tract C-a mining and/or disposal activities. To test the influence of increased moisture on shrub growth for wildlife cover, water harvesting techniques are being incorporated into a simulated mine site/disposal pile bench on a south-facing slope within Box Elder Gulch on Tract C-a.

2. Methods

The design of the simulated mine site/disposal pile bench is presented in Figures 3-4 and 3-5. Water from accumulated snowpack, and runoff from snow melt and rainfall should concentrate along the two rows of shrubs on the 6:1 bench slope (Rows B and C). Increased moisture should also be available to the shrubs in the water bar below the bench (Row E). The rows of shrubs on the 3:1 slope between the bench and the lower water bar (Row D) and the row of shrubs above the bench (Row A) serve as a control, where shrub growth without increased moisture will be monitored.

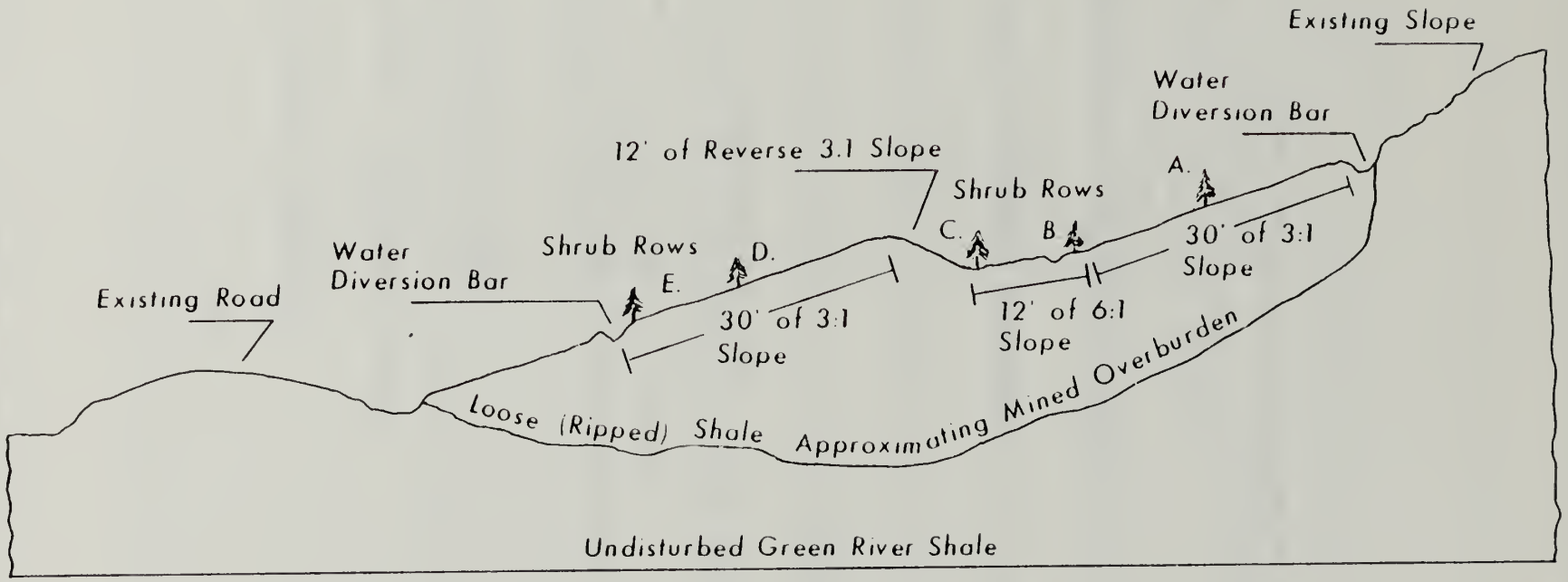


Figure 3-4. Cross Section of Simulated Mine Bench for Testing of Shrub Growth through Water Harvesting.

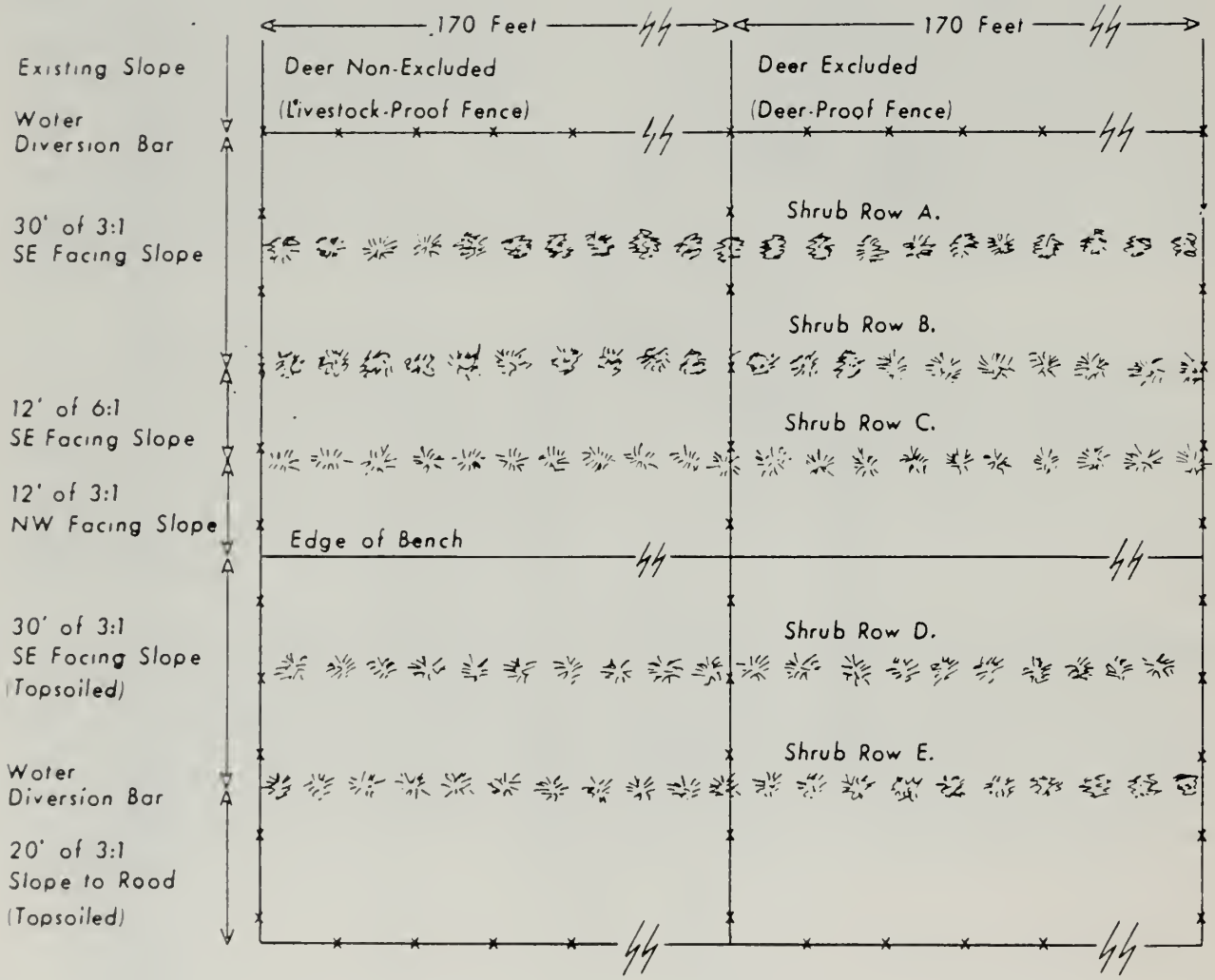


Figure 3.5. Aerial View of Simulated Mine Bench for Testing Enhancement of Shrub Growth through Water Harvesting

Table 3-4. Seed Mixture Used in Final Reclamation by RBOSC

Plant Species	Seeding Rate (Kg/Ha)
Pubescent Wheatgrass (Agropyron trichophorum)	3.0
Western Wheatgrass (Agropyron smithii)	4.2
Streambank Wheatgrass (Agropyron riparium)	2.4
Indian Ricegrass (Oryzopsis hymenoides)	1.8
Green Needlegrass (Stipa viridula)	1.8
Smooth Brome (Bromus inermis)	1.8
Cicer Milkvetch (Astragalus cicer)	1.8
Yellow Sweetclover (Melilotus officinalis)	0.9
Lewis Flax (Linum lewisii)	1.2
Winterfat (Ceratoides lanata)	1.2
Fourwing Saltbush (Atriplex canescens)	1.2
Bitterbrush (Purshia tridentata)	1.2
TOTAL	22.50

In order to establish wildlife cover rapidly, six of the seven shrub species planted in the test area are not normally used as food by deer: fourwing saltbush (Atriplex canescens), New Mexico foresteria (Foresteria neomexicana), Apache plume (Fallugia paradoxa), New Mexico black locust (Robinea neomexicana), old man wormwood (Artemisia abrotanum), and Skunkbrush sumac (Rhus trilobata). Serviceberry (Amelanchier alnifolia), a choice deer food, was included to test the effect of deer browsing pressure on shrub growth. One-half of the test is fenced to exclude deer and cattle, and the other half is fenced to exclude cattle but allow deer entry. All shrub species were planted as tublings in June of 1982. Shrubs were watered at the time of planting and irrigated as necessary during the first summer to ensure establishment; if necessary, one-half of all shrub rows on the bench and in the waterbar will be irrigated for the following two summers, to test the effect of irrigation on shrub growth. All areas between shrub rows were planted with the RBOSC seed mixture illustrated on Table 3-4.

In order to test the effectiveness of the water harvesting technique, moisture content is measured monthly during the growing season within the soil profiles on control and treatment portions of the simulated bench. Permanently placed soil access tubes allow for repeated soil moisture determinations at the same locations using a Troxler® Soil Moisture Probe.

Shrub growth rate is determined by measuring the plant height and diameter of each individual on a seasonal basis. Growth rate of each species is compared for each shrub treatment.

Success of revegetation efforts between shrub rows is monitored along permanently established transects within treatment areas. Transects are placed during the first growing season after planting and area marked at both ends with rebar stakes. Aluminum marking tags identifying the transect number, as well as the beginning and/or end of the transect, are attached to these stakes. Transects are 40 m in length and are oriented such that typical revegetational coverage is sampled perpendicular to the existing slope whenever possible.

Cover of grasses, forbs, and shrubs is estimated annually within sampling frames (1 m^2) placed at five meter intervals along the transects. Placement of these frames is facilitated by stretching a meter tape between the stakes at either end of the transect. Sampling frames are sub-divided into five percent segments and cover of individual species is estimated to the nearest one percent. All data are recorded on field data forms, which are formatted for direct computer entry.

C. Experimental Design and Data Analysis

A comparison of the growth rate by shrub species is made among the enhanced vs non-enhanced watering areas and the deer excluded and non-excluded areas. Analysis of variance techiques will be used to test the following hypothesis.

Ho: The growth rate of a given shrub species is not significantly different:

- o within a shrub row between the deer excluded area and the deer non-excluded area
- o Between rows (as affected by water harvesting and topsoil cover)

This technique is used to examine the differences in growth rate (slope) between rows with increased water and rows with a normal (not enhanced) quantity of water. Data will be adjusted so the intercept is zero ($\alpha=0$). This technique removes bias in sampling and helps to address the question of changes in growth rate ($b_1=b_2=0$).

Success of revegetation efforts between shrub rows will be compared with that of other reclamation assessment efforts.

D. Study to Alter Natural Succession After Fire for Enhanced Deer/Livestock Forage

1. Objective

During RBOSC's commerical operation, disturbance of land will result in the loss of forage for wildlife, primarily mule deer, and for livestock. One means of mitigating these losses is to increase the amount of available forage in undisturbed areas thereby maintaining carrying capacity in the area at, or near, predevelopment levels. RBOSC initiated an experiment in 1982 to determine the feasibility of producing such increases using the habitat modification techniques described below.

2. Methods

A factor important to wintering mule deer is the availability of quality green forage early in the spring. Spring "green-up" time is a period during which deer begin to recoup body nutrients lost throughout the winter. In the spring, deer congregate in large numbers in hay fields and meadows where a high concentration of newly emerged plant sprouts occur. Generally, this critical forage area for deer is also an important summer grazing area for livestock.

Many creek bottoms in the vicinity of Tract C-a which are covered with rank sagebrush, rabbitbrush and greasewood and which serve as quality wintering areas for wildlife. Converting a very small percentage of these bottoms into areas which will provide quality forage for spring "green-up" and summer grazing may increase the carrying capacity of the region.

The use of fire to "set back" plant succession and to remove undesirable plant speices is quite common (Wright et al, 1979). However, several natural fires in Yellow Creek and Duck Creek northeast of Tract C-a have not resulted in vegetation suitable for wildlife in these areas. Therefore, when a natural fire occurred in September 1981 approximately 4 miles down Yellow Creek from the confluence with Corral Gulch (Figure 3-2), steps were taken to

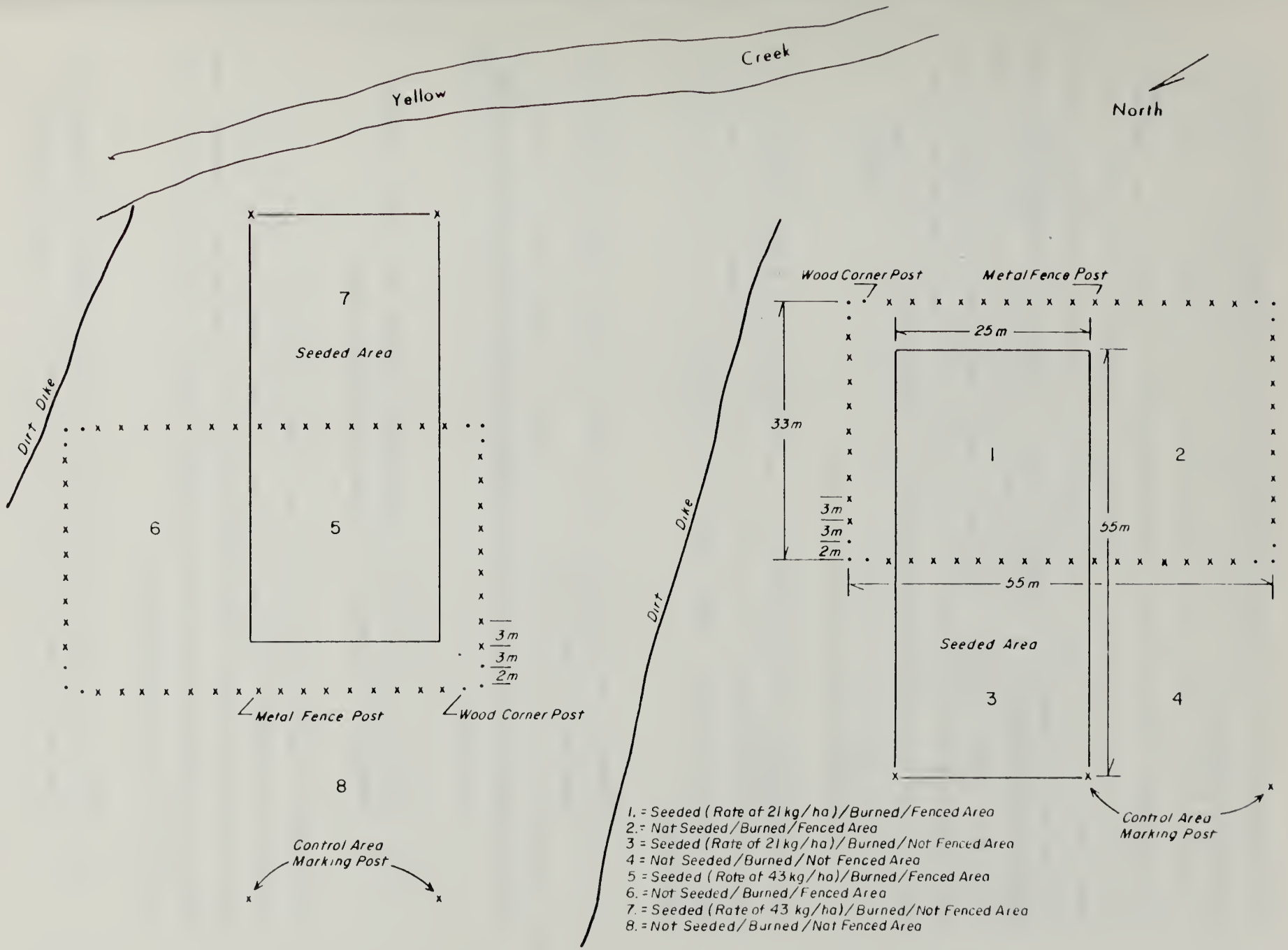


Figure 3-6. Yellow Creek Burn Area Habitat Mitigation Study Design

study the effect of planting selected species, livestock grazing and deer grazing on plant cover.

In late March 1982 the plant species identified in Table 3-4 were seeded in the Yellow Creek Burn Area as specified in Figure 3-6. Two seeding rates were used, 21 and 43 kg/ha (See Figure 3-6), to measure the effect of seeding rate on establishment of desirable forage. (Livestock has been excluded from equal sized sections of both seeded and non-seeded portions of the study area using four strand barbed wire fence.) Range enclosures were placed within the livestock excluded areas to test the effect of deer grazing on plant cover. Plant cover estimates by species are made annually in late summer.

3. Experimental Design and Data Analysis

Cover data will be collected from 8 replicates in each of 8 blocks. In addition, 8 replicates will be caged to prevent deer browsing in the livestock excluded areas. These data will be used to test the following hypotheses:

H_o: There is no significant difference in cover between blocks and cages within each block.

H_o: There is no significant difference between the cover estimates due to fencing.

H_o: There is no significant difference between the cover estimates among planted species in seeded and unseeded areas.

The purpose of caging eight replicates in each livestock excluded area is to provide an exclosure from deer grazing. An additional hypothesis will be used to test the effect of deer grazing pressure on seeded and unseeded areas that are considered exclosed from livestock grazing. Cover data will be used to test the following hypothesis:

H_o: There is no significant difference between seeded and unseeded and caged and uncaged plots due to the exclusion of livestock grazing.

To test the above hypotheses two different Analysis of Variance designs will be used. A two-way Mixed Model (Model III) Analysis of Variance will be used to examine the caging and block differences (Blocks are fixed and caging is random).

	Source of Variation	D.F.	F Ratio	Expected Mean Sources
A	Block	a-1	A/D	$\sigma^2 + \frac{\Sigma\beta^2_{ij}}{a-1}$
B	Caging	b-1	B/D	$\sigma^2 + \frac{\Sigma\alpha^2_{ij}}{b-1}$
C	Block x Caging	(a-1)(b-1)	C/D	$\sigma^2 + \frac{\Sigma(\alpha\beta)^2_{ij}}{(a-1)(b-1)}$
D	Error	ab (n-1)		σ^2
	TOTAL	abn-1		

A second three-way Model III Analysis of Variance will be used to examine the fencing, seeding and caging treatments of the experimental Yellow Creek Burn Area.

	Source of Variation	D.F.	F Ratio	Expected Mean Sources
A	Fencing	a-1	A/F	$\sigma^2 + \frac{bc}{a-1} \sum^{a} \alpha^2$
B	Seeding	b-1	B/E	$\sigma^2 + \frac{ac}{b-1} \sum^{b} \beta^2$
C	Caging	c-1	C/D	$\sigma^2 + \frac{ab}{n-1} \sum^{c} \gamma^2$
D	Fencing x Seeding	(a-1)(b-1)	D/G	$\sigma^2 + \frac{nc}{(a-1)(b-1)} \sum^{ab} (\alpha\beta)^2$
E	Fencing x Caging	(a-1)(c-1)	E/G	$\sigma^2 + \frac{b}{(a-1)(c-1)} \sum^{ac} (\alpha\gamma)^2$
F	Seeding x Caging	(b-1)(c-1)	F/G	$\sigma^2 + \frac{a}{(b-1)(c-1)} \sum^{bc} (\alpha\gamma)^2$
G	Fencing x Seeding x Caging	(a-1)(b-1)(c-1)	G/H	$\sigma^2 + \frac{1}{(a-1)(b-1)(c-1)} \sum^{abc} (\alpha\beta\gamma)^2$
H	Error			σ^2
	Total	abcn-1		

References:

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4.0 AQUATIC ECOLOGY STUDIES

As part of the two-year Environmental Baseline Monitoring Program, data on the aquatic ecosystem were collected at 35 separate sampling stations representative of aquatic habitats found in the vicinity. These stations were located west of Tract C-a, on tract, and downstream from the tract on Corral Gulch, Stake Springs Draw, Yellow Creek and the White River. The studies were designed to inventory the aquatic biota and to determine the baseline characteristics of the aquatic resources. Aquatic biological studies were conducted in conjunction with limited physicochemical studies of surface water. Species composition, relative abundance, and distribution of phytoplankton, zooplankton, macrophytes, periphyton, benthos and fish were determined. In addition, productivity studies were conducted for periphyton and data on the age and growth, condition and reproduction were determined for fish collected from the White River and Lower Yellow Creek. Extensive physical and chemical data on ground and surface water were collected concurrently as a part of the geotechnical and hydrological investigations.

During the MDP period the aquatic studies monitoring program included sampling of periphyton, benthos, physical and chemical components of the aquatic ecosystem. Evaluation of this program has shown periphyton to be an extremely variable component in the aquatic ecosystem and unreliable as an indicator of impacts due to oil shale development. Benthic macroinvertebrates were determined to be better, more reliable, indicators of changes in the aquatic community near Tract C-a.

The interim aquatic program is designed to provide continued monitoring of the possible effects of tract development activities to date on the downstream aquatic system. Sampling of selected physical and chemical parameters and benthic macroinvertebrates at three selected sites in Corral Gulch and Yellow Creek will provide this information.

4.1 ABIOTIC MONITORING

A. Field Measurements

1. Objectives

The objectives of taking field measurements during the interim aquatic monitoring studies are to evaluate selected physical and chemical components at each sampling site and to relate habitat and water quality data to biological conditions observed at each site.

2. Methods

a. Parameters - The field parameters and stream survey indexes selected for these monitoring studies are those which are more likely to be influenced by development activities (e.g., increased siltation and turbidity, changes in flows) and which are of importance to the aquatic community on and near Tract C-a. The measured parameters include stream velocity, turbidity, dissolved oxygen, pH, alkalinity, specific conductance, water temperature, depth and width. Three replicates of each parameter are taken each time they are sampled.

b. Monitoring locations - The sampling locations for the RBOSC aquatic monitoring program are shown in Figure 4-1 and include:

- Station CG-1 at the U.S.G.S. gaging station in Corral Gulch east of Tract C-a just below the confluence with Box Elder Gulch.
- Station YC-1 on Yellow Creek downstream of the confluence of Stake Springs Draw and Corral Gulch.
- Station YC-2 at the road crossing of Yellow Creek approximately 6 miles from the confluence of White River and Yellow Creek.

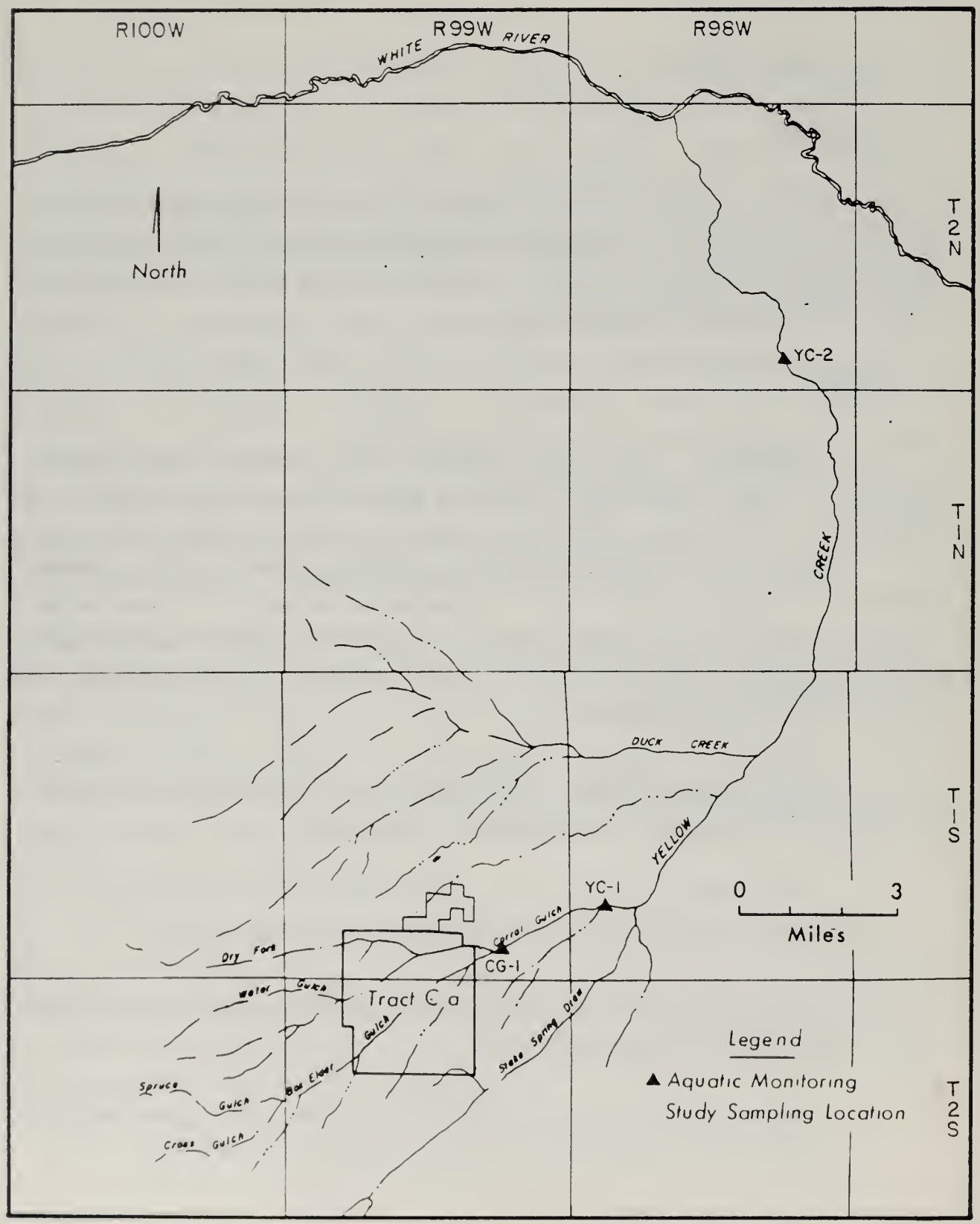

Figure 4-1. Locations of Aquatic Ecology MDP Sampling Sites

These stations were chosen because they are representative of the primary habitat types found in the area and because they are in a location that will provide for detection of impacts that may result from Tract C-a activities. Normally there are several miles of dry stream bed between YC-1 and YC-2.

c. Monitoring Frequency and Schedule - Sampling will be conducted three times a year to allow for comparison of seasonal changes. Sampling will be carried out during the months of April, July and October.

d. Data Collection Methods - Physical characteristics of the streams are measured concurrently with the collection of chemical and biological samples. Stream velocity is measured with a Gurley flow meter or equivalent. The turbidity of each sample is determined with a Hach Photometric Turbidimeter or equivalent.

Other parameters (and methods of measurement), which are determined in the field, include pH (portable meter), specific conductance (portable meter), water temperature (thermistor or equivalent), dissolved oxygen (portable meter), depth, width and total alkalinity (colorimetric; APHA, 1976).

3. Experimental Design

Field data collected as part of the aquatic studies program are used in conjunction with the chemical and biological data to characterize the aquatic habitat and define changes which may occur. Statistical evaluation of the physical conditions will be completed using a Three-way Model I Analysis of Variance. The following hypotheses will be tested:

H_o: There are no significant differences in the field measurements between years.

H_o: There are no significant differences in the field measurements between sampling stations.

H_o: There are no significant differences in the field measurements between seasons.

The Analysis of Variance table (Table 4-1) depicts the statistical design used for the analysis of physical measurements and the water quality parameters. If there is a significant difference between the variances of the interaction terms and main effects, a Duncan's Multiple Range Test will be run to determine the variability in means of the main effect.

B. Water Quality Measurements

1. Objectives

The objective of including water quality studies in the interim aquatic studies program is to determine if site specific changes in aquatic biological populations are due, at least in part, to changes in water quality. Analysis of the data will be conducted to monitor year-to-year, seasonal, and station differences, and to monitor natural and development-related variation in water quality.

2. Methods

Chemical parameters for water quality studies (Table 4-2) are the same as those selected for the hydrology monitoring program (Section 5.0). The methods used to analyze those constituents are also listed in Section 5.0.

a. Constituents - Constituents to be included in the basic water quality monitoring program are listed in Table 4-2.

b. Monitoring Locations - Three sampling sites (Figure 4-1) are included in the aquatic water quality monitoring program. These stations are the same as those used to monitor physical parameters. Water quality data collected in the hydrology monitoring program can be used to supplement data collected in the aquatic monitoring program.

Table 4-1. Three-way Analysis of Variance (Model I) Design for Physical Measurements, Water Quality, and Benthos Density Estimates.

Source	df	F-Test	Expected MS. (Model 1)
A. Years	a-1	A/F	$\sigma^2 + \frac{bc}{a-1} \sum^{a} \alpha^2$
B. Stations (3 stations)	b-1	B/E	$\sigma^2 + \frac{ac}{b-1} \sum^{b} \beta^2$
C. Seasons (Spring, Summer, Fall)	c-1	C/D	$\sigma^2 + \frac{ab}{c-1} \sum^{c} \Upsilon^2$
D. Years x Stations	(a-1)(b-1)	D/G	$\sigma^2 + \frac{c}{(a-1)(b-1)} \sum^{ab} (\alpha\beta)^2$
E. Years x Seasons	(a-1)(c-1)	E/G	$\sigma^2 + \frac{c}{(a-1)(c-1)} \sum^{ac} (\alpha\beta)^2$
F. Stations x Seasons	(b-1)(c-1)	F/G	$\sigma^2 + \frac{a}{(b-1)(c-1)} \sum^{bc} (\beta\Upsilon)^2$
G. Year x Station x Season	(a-1)(b-1)(c-1)	G/H	$\sigma^2 + \frac{1}{(a-1)(b-1)(c-1)} \sum^{abc} (\alpha\Upsilon)^2$
H. Error Term	abc(n-1)		σ^2
Total	(nabc)-1		

Table 4-2. Field-measured Parameters and Water Quality Constituents Measured at Aquatic Sampling Sites

- Field Data
  - stream velocity and flow
  - specific conductance
  - turbidity
  - dissolved oxygen
  - pH
  - temperature
  - alkalinity
  - width
  - depth
  - stream substrate
  - suspended solids

- Water Quality
  - total dissolved solids
  - calcium
  - magnesium
  - potassium
  - sodium
  - bicarbonate
  - carbonate
  - chloride
  - nitrate
  - sulfate
  - fluoride
  - ammonia
  - total phosphate
  - boron
  - silica (SiO_2)
  - iron
  - dissolved organic carbon
  - arsenic
  - selenium
  - vanadium
  - molybdenum
  - mercury

c. Monitoring Frequency and Schedule - Sampling and analysis of basic water quality parameters are conducted three times a year at the same time biological samples are collected to provide direct time and space comparisons. Sampling is scheduled for April, July and October.

d. Sample Collection, Analysis and Quality Assurance - Table 5-7 in Section 5 lists the analytical methods and limits of detection for the water quality analyses for the hydrology and aquatic ecology programs.

3. Experimental Design and Data Analysis

To fulfill the objectives of these studies, three hypotheses will be tested using a Three-way Model 1 Analysis of Variance. If there is a significant difference in the variances between the interactions and main effects then a Duncan's Multiple Range Test will be used to examine the variability in the means of the water quality parameters. The hypotheses to be tested are as follows:

H_o: There is no significant difference in the water quality parameters between years.

H_o: There is no significant difference in the water quality parameters between seasons.

H_o: There is no significant difference in the water quality parameters between stations.

4.2 BIOTIC MONITORING

As indicated in the introduction to the aquatic studies program, selection of biological parameters for inclusion in the RBOSC interim monitoring program was based upon a comprehensive analysis of the aquatic baseline data, MDP monitoring data, and upon an assessment of potential impacts of past tract operations.

A. Benthic Macroinvertebrates

1. Objectives

The objectives of the benthic macroinvertebrate studies are to monitor relative abundance, species composition, density, and diversity of the benthic communities, in order to identify and document changes (both natural and project related).

The benthos data from these studies will be compared to the physical and chemical data to provide an assessment of the changes in the aquatic habitat on and near Tract C-a due to natural variation, project related or other activities.

2. Methods

a. Parameters - The benthos population characteristics selected for evaluation include species composition, relative abundance and species density and diversity.

b. Monitoring Locations - Samples of the benthic invertebrate community will be collected at the same three monitoring locations as described in Section 4.1 and depicted on Figure 4-1.

c. Monitoring Frequency and Schedule - Samples will be collected three times a year to allow for seasonal comparison of monitoring and baseline data. Monitoring is conducted during April, July and October. Previous

testing of baseline and MDP monitoring data indicated that seasonal grouping (Spring, Summer, and Fall) will adequately account for changes in the benthic community.

d. Sample Collection, Analysis and Quality Assurance - At each sampling site three replicate samples are collected with a modified Hess sampler (FD-8-522 cm^2). It consists of a metal frame with #30 mesh (0.6 mm aperature) side curtains. The side screening prevents the capture of drifting organisms while allowing the passage of stream water to wash collected organisms into the downstream side collecting sock.

After collection, benthos samples are washed using a U.S. Standard No. 30 sieve, and are preserved with neutralized 10 percent formalin.

Standardized methods of sample processing and analysis are utilized in the laboratory and documented in the Quality Assurance program. Samples are rinsed in sieves to remove specimens from sediment. Organisms are then hand-sorted under magnification and are stored in plastic capsules containing 70 percent ethanol.

Chironomidae and Oligocheata are cleared in xylene and then mounted on permanent slides in Canada balsam. Only complete oligochaetes with intact anterior portions are enumerated.

Other benthic organisms are generally identifiable to genus without special preparation. Organisms are identified to the lowest taxon practical. Individuals are usually identified under the dissecting microscope or on temporary slides (under water) under a compound microscope.

Only those individuals which are living at the time of collection, as indicated by presence of fleshy tissue, are enumerated for the purpose of estimating populations. Empty mollusc shells, exuvia, reproductive structures, etc. are retained as aids in identification and for compilation of qualitative species lists, but are not used to estimate population densities. A special reference or voucher collection is maintained apart from other specimens.

3. Experimental Design

In fulfilling the objectives of these studies, the following hypotheses will be tested:

H_o: There is no significant difference in the species density of benthos between years, seasons, or stations.

Density will be tested by utilizing a Three-way Model 1 Analysis of Variance technique (Table 4-2). Indices of similarity, evenness and richness will also be used in assessing trends in the benthic species composition. A similarity index can be used to evaluate changes in relative abundance, along with ranking techniques.

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5.0 HYDROLOGY STUDIES

The hydrology monitoring program includes sampling of surface streams, alluvial aquifers, deep aquifers and selected operations activities (e.g. composite reinjection flows). The focus of the interim period is to monitor the potential impacts of past and continued activities on Tract C-a. The background levels of hydrologic parameters have been characterized by studies conducted since 1974.

5.1 PHYSICAL MONITORING

A. Overview

Physical parameter monitoring includes the measurement of ground water levels and surface water flows. In addition, field measurements are made of water temperatures, specific conductance and pH at selected monitoring sites. USGS stream gaging stations are instrumented to measure surface flows onto and leaving Tract C-a and sediment yield from the tract. The sampling program is presented in Section 5.2 along with the water chemistry monitoring program.

B. Data Presentation and Analysis

Ground water level contour maps are periodically developed to examine the cone of depression resulting from mine dewatering operations on Tract C-a. In addition, time series plots of physical parameters sampled at specific stations are prepared to examine temporal cycles. Comparison of minimum, maximum and mean values across monitoring years provides a measure of temporal trends.

5.2 CHEMICAL MONITORING

A. Overview

Both basic water quality (BWQ) and trace water quality (TWQ) are monitored at selected sites. The constituents measured as part of the BWQ sampling are as follows:

- General water quality measures
  - total dissolved solids
  - specific conductance
  - pH
  - alkalinity
- Major inorganics
  - calcium
  - magnesium
  - potassium
  - sodium
  - bicarbonate
  - carbonate
  - chloride
  - nitrate
  - sulfate
  - sulfide
  - fluoride
  - ammonia
  - phosphate
  - boron
  - silica (SiO_2)
  - iron
- Dissolved organic carbon
- Trace elements
  - arsenic
  - selenium
  - vanadium
  - molybdenum
  - mercury

Constiuents included in the TWQ sampling are as follows:

- aluminum
- barium
- beryllium
- bismuth
- bromide
- cadmium
- chromium
- copper
- gallium
- germanium
- iron
- lead
- lithium
- manganese
- nickel
- strontium
- titanium
- zinc
- zirconium

B. Monitoring Stations and Schedule

The monitoring schedules for deep wells, alluvial wells and surface stations are presented in Tables 5-1, 5-2, and 5-3, respectively. In addition to the program outlined on Table 5-1, a semi-annual (April and September) survey for water levels will be conducted which will include the wells listed in Table 5-4 (and Figure 5-1). Alluvial wells are shown in Figure 5-2. The surface flow data listed in Table 5-3 will be supplemented by quarterly measurements of the leading edge (the maximum extent of downstream surface flow in Yellow Creek) and daily measurements of water levels in mine water and sour water sumps within the mine.

The USGS gage station monitoring program is as follows:

Station D - continuous flow, specific conductance, temperature, sediment
- quarterly BWQ, annual TWQ

Station B - continuous flow, specific conductance, temperature
- semi-annual BWQ

Station C - continuous flow, specific conductance, temperature
- annual (high flow) BWQ

These and other surface stations are shown in Figure 5-3. Surface stations are further defined as follows:

o USGS:
D - Corral Gulch east of Tract C-a (09306242)
B - Corral Gulch near west boundary of Tract C-a (09306235)
C - Box Elder Gulch near west boundary of Tract C-a (09306240)

o Springs:

SPG-3	Near head region of Corral Gulch
SPG-4	On tributary to Corral Gulch west of Tract C-a
SPG-5	Stake Springs Draw, southeast of Tract C-a
SPG-14	Corral Gulch east of Tract C-a
SPG-20	Near head region of Duck Creek
SPG-MILL	Separate flow from Corral Gulch near USGS - D

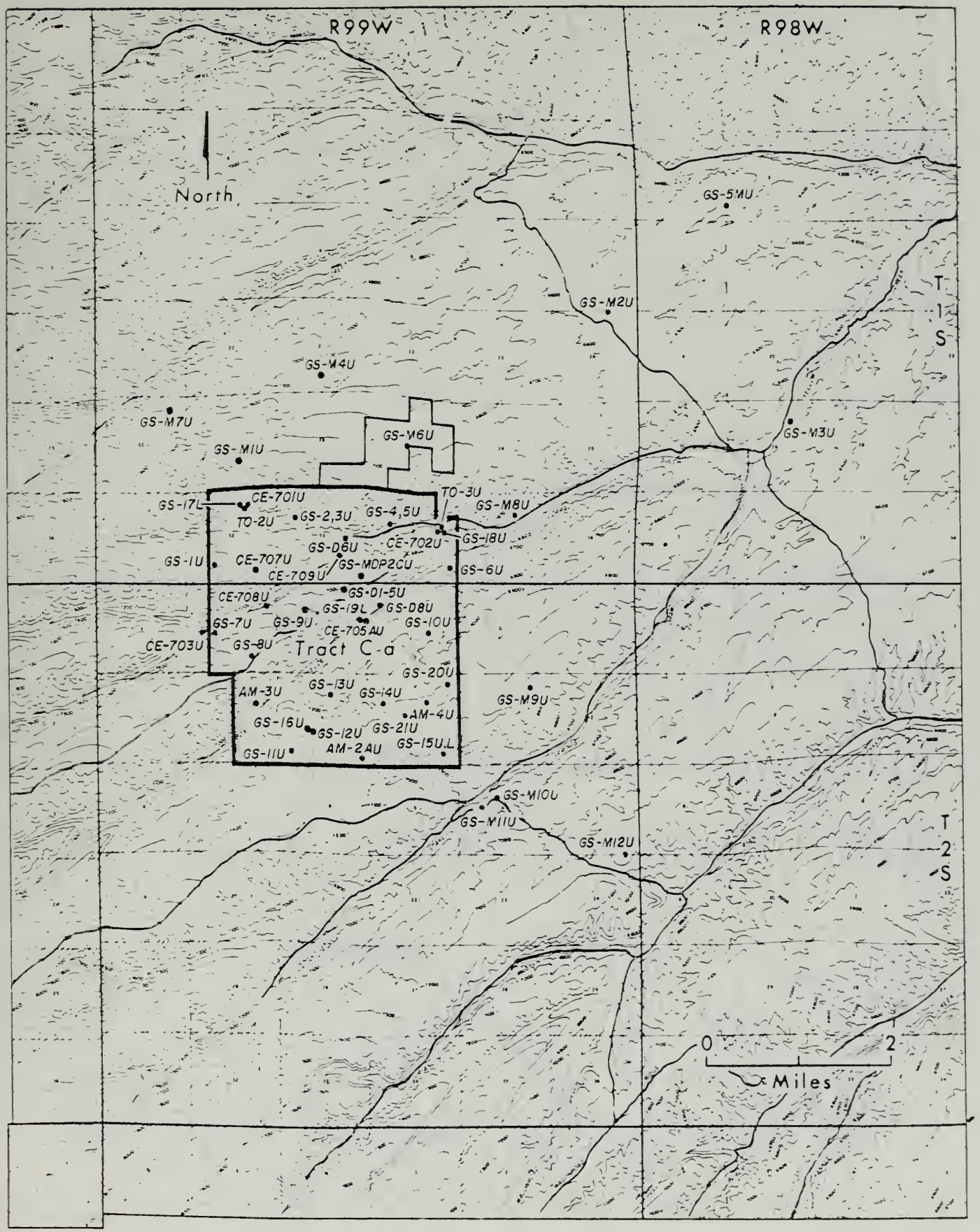


Figure 5-1. Deep Aquifer Monitoring Stations

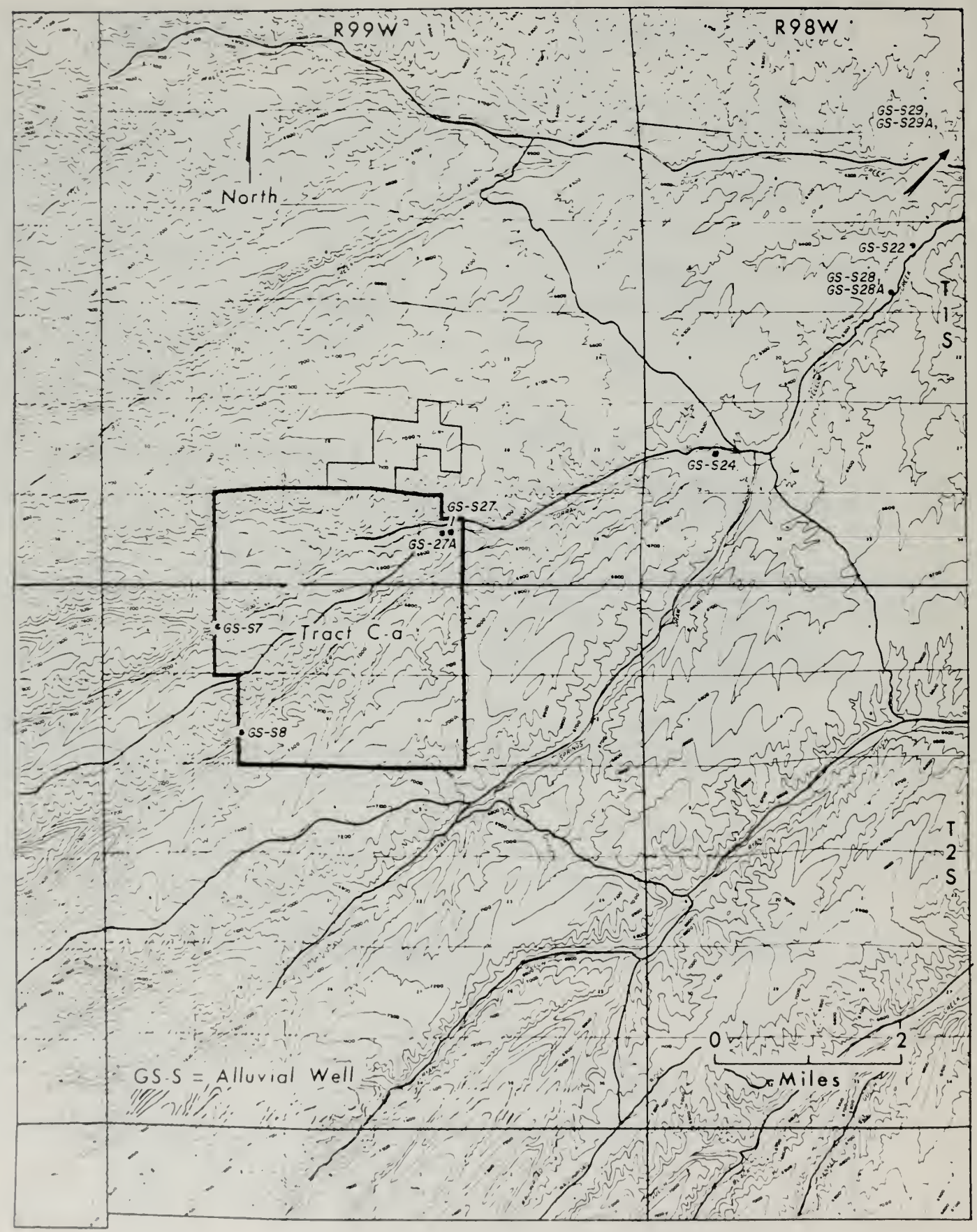


Figure 5-2. Alluvial Monitoring Stations

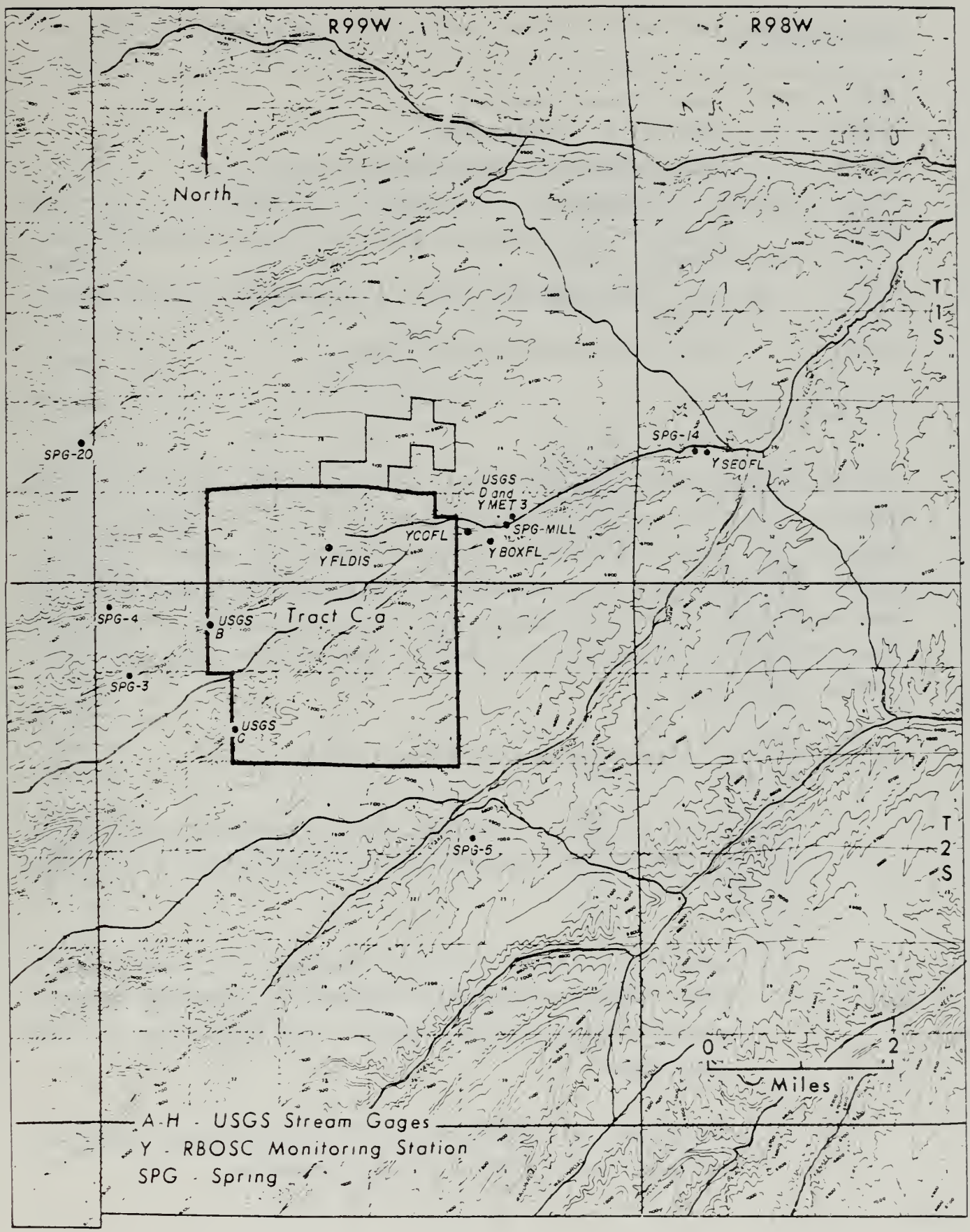


Figure 5-3. Surface Discharge Monitoring Stations

Other Stations:

Jeffery Pond	East shaft settling pond
YCOINJ	Composite reinjection flow
YFLDFS	Discharge point for sewage treatment plant
YMET3	At USGS Station D
YBOXFL	Box Elder Gulch upstream from the confluence with Corral Gulch (flume)
YCOFL	Corral Gulch upstream from the confluence with Box Elder Gulch (flume)
SEOFL	Corral Gulch near 84-Ranch (flume)

3. Data Analysis

The hydrology monitoring program has been designed to continue monitoring the effects of past and on-going activities on Tract C-a. To provide this analysis, the monitoring stations are divided into two "areas" - the MIS modular development area and the dewatering/reinjection/discharge area. For each area, Type I (control), Type II (near field, potentially affected) and Type III (far field, potentially affected) stations have been identified (Tables 5-5 and 5-6).

Hydrology monitoring data will be evaluated as follows:

a. Descriptive statistics (minimum, maximum, mean where appropriate) will be computed for the report period for each group of monitoring stations to:

   - o Compare baseline (or other past periods) with report period data. Baseline descriptive statistics, including standard deviation and confidence intervals, will be utilized for these comparisons.

   - o Compare control versus potentially affected stations both for the report period and for the baseline period.

Table 5-1. Interim Hydrology Monitoring Program for Deep Aquifer Wells

	Monitoring Frequency			
Deep Wells	Weekly	Monthly	Quarterly	Annually
GS-D1U	WL		FWQ,BWQ	TWQ
GS-D3U	WL		FWQ,BWQ	TWQ
GS-D6U		WL		
GS-D8U		WL		
GS-9U		WL		
GS-MDP2CU	WL		FWQ,BWQ	TWQ
CE-702U	WL		FWQ,BWQ	TWQ
CE-709U	WL		FWQ,BWQ	TWQ
CE-705AU	WL		FWQ,BWQ	TWQ
CE-708U				WL, FWQ
GS-M1U				WL, FWQ
GS-M3U			FWQ	BWQ,TWQ
GS-M7U				WL, FWQ
GS-M8U				WL, FWQ
GS-M9U				WL, FWQ
GS-M10U			FWQ	BWQ,TWQ
GS-M12U			FWQ	BWQ,TWQ
AM-3U			FWQ	BWQ,TWQ
GS-15U			FWQ	BWQ,TWQ
GS-15L			FWQ	BWQ,TWQ
GS-17L				WL, FWQ

Table 5-2. Interim Hydrology Monitoring Program for Alluvial Wells

	Monitoring Frequency		
Deep Wells	Weekly	Quarterly	Annually
GS-S7	WL		FWQ,BWQ
GS-S8	WL		FWQ,BWQ
GS-S27	WL	FWQ,BWQ	TWQ
GS-S27A		WL	FWQ,BWQ
GS-S24		WL	FWQ,BWQ
GS-S28(2 wells)		WL	FWQ,BWQ
GS-S28A(2 wells)		WL	FWQ,BWQ
GS-S22		WL	FWQ,BWQ
GS-S29(2 wells)		WL	

Table 5-3. Interim Hydrology Monitoring Program for Surface Stations

	Monitoring Frequency				
Surface Stations	Daily	Weekly	Monthly	Quarterly	Annually
Jeffrey Pond	flow	FWQ		BWQ	TWQ
YCOINJ	flow, FWQ			BWQ	TWQ
YFLDIS	flow, FWQ (NPDES)				
YMET3		flow, FWQ		BWQ	TWQ
YBOXFL		flow, FWQ		BWQ	TWQ
YCOFL		flow, FWQ		BWQ	TWQ
SEOFL			flow, FWQ	BWQ	TWQ
Springs					
SPG-3				flow, FWQ	
SPG-4				flow, FWQ	
SPG-5				flow, FWQ	
SPG-MILL				flow, FWQ	
SPG-20				flow, FWQ	

Table 5-4. Deep Aquifer Stations

Station Label		Physical Description
GS-1U	T1S, R99W	Section 32 - Northwest Corner
GS-2-3U	T1S, R99W	Section 33 - North side - Dry Fork
GS-4-5U	T1S, R99W	Section 34 - Northeast corner - Corral Gulch
GS-6U	T1S, R99W	Section 34 - Northeast Corner - Box Elder Gulch
GS-9U	T2S, R99W	Section 4 - Center - Between Box Elder and Corral Gulch
GS-10U	T2S, R99W	Section 3 - East side
GS-11U	T2S, R99W	Section 9 - South side - Between Rinky Dink and Box Elder Gulch
GS-12U	T2S, R99W	Section 9 - South side - Between Rinky Dink and Box Elder Gulch
GS-13U	T2S, R99W	Section 9 - South side - Between Rinky Dink and Box Elder Gulch
GS-15 U,L	T2S, R99W	Section 10 - Southeast Corner
GS-17L	T1S, R99W	Section 32 - Northwest Corner - Dry Fork
GS-19L	T2S, R99W	Section 4 - Center - Box Elder Gulch
GS-20U	T2S, R99W	Section 10 - Southeast Corner - East of Rinky Dink Gulch
GS-21U	T2S, R99W	Section 10 - Southeast Corner - East of Rinky Dink Gulch
TO-2U	T1S, R99W	Section 32 - Northwest Corner - Dry Fork
TO-3U	T1S, R99W	Section 34 - Northeast Corner - Corral Gulch
CE-701U	T1S, R99W	Section 32 - Northwest Corner - Dry Fork
CE-702U	T1S, R99W	Section 34 - Northeast Corner - Corral Gulch
CE-705AU	T2S, R99W	Section 4 - Center - Box Elder Gulch
CE-707U	T1S, R99W	Section 32 - Northwest Corner - Between Dry Fork and Corral Gulch
CE-708U	T2S, R99W	Section 5 - North of Corral Gulch
CE-709U	T1S, R99W	Section 33 - Near MIS Area
AM-2AU	T2S, R99W	Section 9 - South side
AM-3U	T2S, R99W	Section 8 - Southwest Corner - Box Elder Gulch

Table 5-4. Deep Aquifer Stations (Continued)

Station Label		Physical Description
GS-M1U	T1S, R99W	Section 29 - 0.5 m. North of Tract
GS-M2U	T1S, R99W	Section 24 - 2.0 m. Northeast of Tract
GS-M3U	T1S, R98W	Section 29 - 3.5 m. Northeast of Tract
GS-M4U	T1S, R99W	Section 21 - 1.5 m. North of Tract
GS-M5U	T1S, R98W	Section 8 - 4.0 m. Northeast of Tract
GS-M6U	T1S, R99W	Section 27 - 0.5 m. North of Tract
GS-M7U	T1S, R99W	Section 30 - 0.5 m. Northwest of Tract
GS-M8U	T1S, R99W	Section 35 - 0.5 m. East of Tract
GS-M9U	T2S, R99W	Section 11 - 0.5 m. East of Tract
GS-M10U	T2S, R99W	Section 14 - 0.5 m. Southeast of Tract
GS-M11U	T2S, R99W	Section 14 - 0.5 m. Southeast of Tract
GS-M12U	T2S, R99W	Section 13 - 2.0 m. Southeast of Tract
GS-D1U	T1S, R99W	Section 33 - MIS Area
GS-D3U	T1S, R99W	Section 33 - MIS Area
GS-D6U	T1S, R99W	Section 33 - Center of Tract - Corral Gulch
GS-D8U	T2S, R99W	Section 3 - East side - Box Elder Gulch
GS-MDP2CU	T1S, R99W	Section 33 - MIS Area

Table 5-5. Hydrology Monitoring Program - MIS Development Area

Station Class.	Station Identification	
Type I Control	Streams	
	B-USGS	C-USGS
	Springs and Seeps	
	SPG-3	
	SPG-4	SPG-14
	SPG-5	SPG-MILL
	Alluvial Aquifer	
	GS-S7	GS-S8
	Deep Aquifer	
	GS-15L	GS-15U
	CE-708U	GS-9U
Type II Near Field	Streams	
	D-USGS	Y MET 3
	YCOFL	YBOXFL
	YSEOFL	
	Alluvial Aquifer	
	GS-S27	
	GS-S27A	
	Deep Aquifer	
	CE-709U	CE-702U
	GS-MDP2CU	CE-705AU
Type III Far Field		
	Alluvial Aquifer	
	GS-S24	
	Deep Aquifer	
	GS-M3U	

Table 5-6. Hydrology Monitoring Program - Dewatering/Reinjection/Discharge

Station Class.	Station Identification
Type I Control	Springs & Seeps SPG-3 SPG-5 SPG 4 SPG-MILL Deep Aquifer GS-M9U AM-3U GS-MIOU GS-9U GS-M12U CE-708U
Type II Near Field	Mine Seepage Mine Water and sour water sumps Composite reinjection Discharge Sites/Streams YFLDIS Deep Aquifer GS-D1U GS-D6U GS-D3U GS-D8U GS-MDP2CU CE-702U
Type III Far Field	YLDGEDGE - leading edge Deep Aquifer GS-M3U CE-702U CE-709U GS-17L

These comparisons, via tabular listings, will be made for each constituent in the monitoring program.

b. MANOVA will be employed to provide the following for selected constituents included in the basic water quality program:

- o An evaluation of temporal variability (e.g., baseline or other past period versus report period).
- o An evaluation of spatial variability (e.g., control versus potentially affected areas).

In addition to these main effect (time, space) evaluations, interaction effects and, when appropriate, multiple range tests will be examined to provide insight into possible development-related impacts on the hydrologic system.

c. If appreciable changes are observed from the above outlined analyses, then the following additional analyses will be performed:

- o Evaluation of raw data time series to identify sources/causes of change.
- o MANOVA analysis on all monitoring constituents for which an adequate sample size exists.

4. Chemical Analysis

Analytical methods to be employed are listed in Table 5-7. Also included in the table are detection limits of the indicated method.

Standard laboratory quality control procedures will be followed for the water quality analysis. Elements of the QC/QA program are as follows:

Table 5-7. Analytical Methods and Limits of Detection

Parameter	Reference	Method No.	Detection Limit
Temperature	2	170.1	0.5° C
pH	2	150.1	0.01 pH units
Electrical conductivity	2	120.1	10 umhos-cm
Bicarbonate	1	403	5.0 mg/l
Carbonate	1	403	1.0 mg/l
Sulfate	2	375.3	5 mg/l
Sulfide	2	376.1	1.0 mg/l
Chloride	2	325.3	0.5 mg/l
Nitrate-N	2	352.1	0.1 mg/l
Ammonia-N	1	418.0	0.1 mg/l
Fluoride	2	340.2	0.05 mg/l
Dissolved solids	2	160.1	15.0 mg/l
Phosphate	2	365.3	0.02 mg/l
Bromide	1	406	0.1 mg/l
Total alkalinity	1	403	5 mg/l
Al	2	202.1	0.1 mg/l
As	2	206.3	0.01 mg/l
Ba	2	208.1	0.1 mg/l
B	2	212.3	0.05 mg/l
Be	1	304 A	0.01 mg/l
Bi	3	Bi	0.005 mg/l
Ca	2	215.1	0.01 mg/l
Cd	2	213.1	0.01 mg/l
Cr	2	218.1	0.01 mg/l
Cu	2	220.1	0.01 mg/l
Fe (Total)	2	236.1	0.05 mg/l
Ga	3	Ga	0.5 mg/l
Ge	3	Ge	0.05 mg/l
Li	1	312 A	0.01 mg/l

Table 5-7. (Continued)

Parameter	Reference	Method No.	Detection Limit
Pb	2	239.1	0.01 mg/l
Mg	2	242.1	0.01 mg/l
Mn	2	243.1	0.01 mg/l
Hg	2	245.1	0.0004 mg/l
Mo	2	246.1	0.1 mg/l
Ni	2	249.1	0.05 mg/l
K	2	258.1	0.01 mg/l
Se	2	270.3	0.01 mg/l
Sr	1	321 A	0.01 mg/l
Na	2	273.1	0.01 mg/l
Si (SiO_2)	1	301 A	0.5 mg/l
Ti	3	Ti	0.5 mg/l
V	2	286.1	0.5 mg/l
Zn	2	289.1	0.01 mg/l
Zr	3	Zr	10.0 mg/l
DOC	2	415.1	1.0 mg/l

REFERENCE NO.

1 "Standard Methods for the Examination of Water and Wastewater," 14th Edition (1976), by American Public Health Association.

2 "Methods for Chemical Analysis of Water and Wastes," March, 1979 by Environmental Monitoring and Support Laboratory, U.S. Environmental Protection Agency. (Publication EPA 600/4-79-020)

3 Perkin-Elmer Analytical Methods for Atomic Absorbtion Spectrophotometry, 1979 edition.

- o Instrument Quality Control - Instruments are checked for accuracy and consistency on a regular schedule. Sample blanks, standards, standard additions and spiked samples are routinely used. Periodic instrument service schedules are maintained.

- o Laboratory Supplies and Reagents - Clean water supplies meeting EPA specifications are utilized, as are ACS analytical grade reagents and solvents and Class A volumetric glassware.

- o Internal Quality Control - Duplicate samples, spiked samples, internal unknowns, TDS-conductivity and cation-anion balances are routinely utilized to verify precision and accuracy of analysis.

- o Sample Tracking - Procedures have been developed to trace samples from sample collection through entry of results into the computer data base.

- o Blank Reference Samples - Supplied by OSO, EPA or other appropriate agencies or organizations.

5.3 DATA SCREENING

Hydrology data will be screened as soon as possible after collection using the following procedures:

1. Field measurements will be compared to data screen limits (e.g. 10-90 percent confidence intervals calculated using past data sets)

2. Exceedances of screen limits will be examined for data trends and need to resample, check standards, etc.

3. Exceedances will be documented.

4. Water quality data will be provided semi-annually to the OSO.

5. Spills, etc. will be reported to the OSO as in the past.

6.0 QUALITY ASSURANCE, DATA MANAGEMENT, AND REPORTING PROCEDURES

6.1 QUALITY ASSURANCE

The RBOSC Quality Assurance Program is designed to provide documentation that the environmental monitoring program is being conducted in accordance with the approved scope of work and in compliance with standard, approved scientific methods and procedures. In addition, the program must be as thorough and concise as possible, providing organized, accessible quality assurance information. The RBOSC program meets these needs.

The following list contains the basic components of the RBOSC Quality Assurance Program.

- Use of program-specific field manuals by technicians to assure consistency in sampling
- Regular supervisory checks of all data sheets
- Verification of laboratory results by splits, ion balances, performance samples, and expert review
- Data Management input and subsequent computerized screening of data.
- Review of reports including verification of data in reports
- Periodic internal and external audits of quality assurance files and monitoring program procedures and data

Documentation of the above procedures is contained in a documents file at the RBOSC Environmental Affairs Department office in Denver. Documents retained in this file include monitoring program scopes-of-work, correspondence relating to the monitoring program, summaries of data collection techniques, records of data verification, reviews of monitoring reports, and results of monitoring program audits.

6.2 DATA MANAGEMENT

The RBOSC Data Management System (EADDMS) is an integrated process designed to enable rapid and relatively easy access and retrieval of data collected in the RBOSC Environmental Monitoring Programs. The data management system also functions as a quality assurance component, as data are reviewed and verified several times prior to final analysis and interpretive reporting. The data management system involves four activities: data verification, processing, analysis, and output. Figure 6-1 gives a brief system overview of Data Management activities.

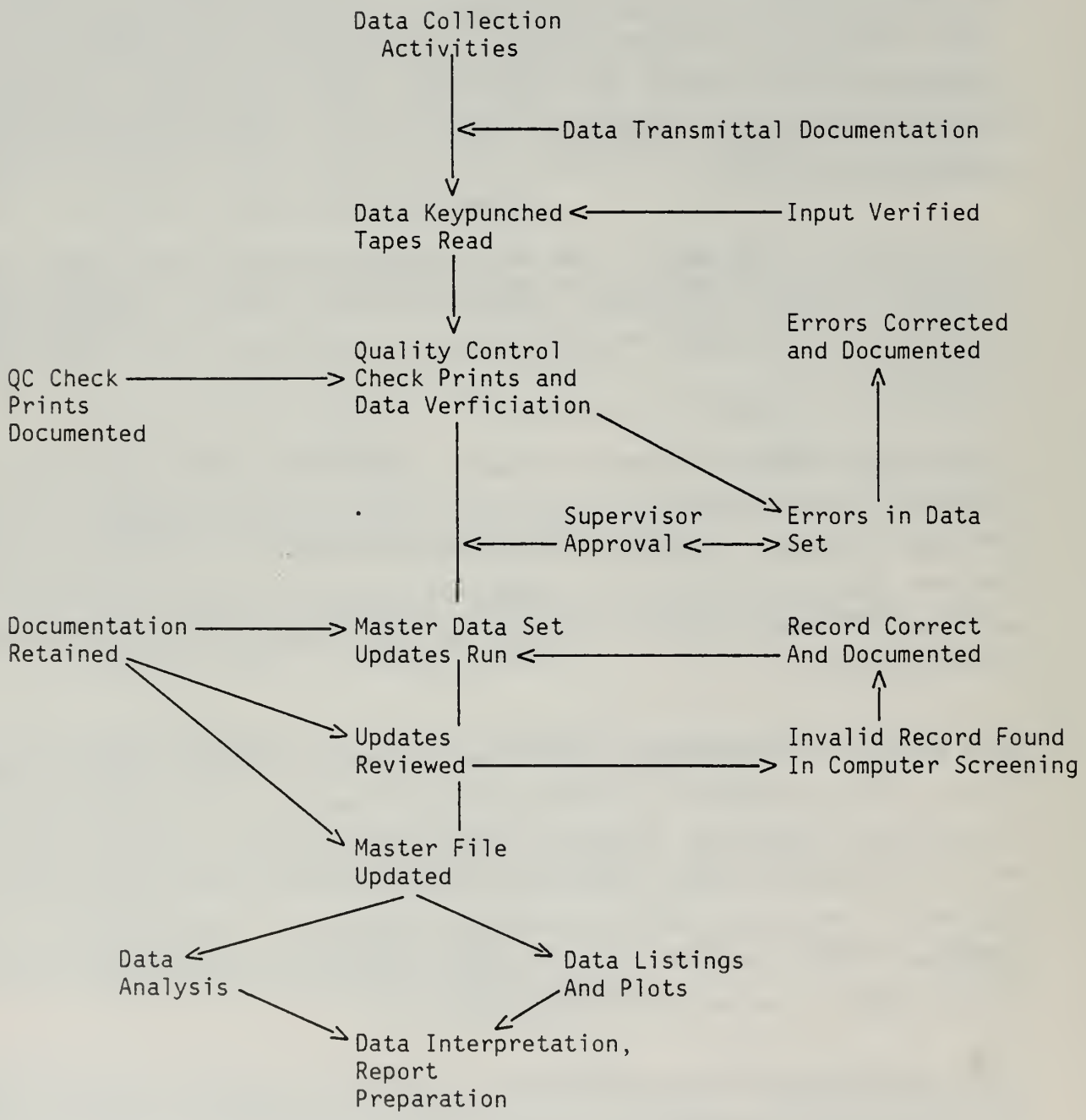
Verification of the data is the most important aspect of the RBOSC data management system. Stringent, documented quality control procedures are implemented on all manual and digital data. This ensures credibility of the data base.

Processing of RBOSC environmental data is a multistep process that varies in complexity and sophistication with each of the monitoring programs. All data are sent to Denver and merged into an online sequential data base for each program. Data are compiled on an appropriate storage medium and reviewed for accuracy and completeness, either by an RBOSC specialist or computerized editing routines.

Data analysis is performed as specified in the approved monitoring program Scope of Work. Additional analyses are performed as requested by program supervisors. Evaluation, updating, merging and storage of data are completed as part of this activity. Data analysis also involves testing and implementing new or previously defined analytical techniques. Interpretation of the analyses is also verified. This includes independent review and discussion between qualified scientists in each discipline.

RBOSC reporting requirements are such that the data management system must be flexible enough to generate the output necessary to meet these requirements. Data lists, tables, plots, and analysis output are routinely generated and formatted as needed for the various reports required of RBOSC.

Figure 6-1. System Overview of Data Management Activities



6.3 REPORTING

The calendar year (January-December) is the basic reporting period for the environmental monitoring program.

Mid-year data reports are submitted to the OSO on September 30 (or nearest work day following the 30th) of each monitoring program year. Mid-year reports contain reduced and raw data collected during the January through June period. Overviews of each technical discipline area are provided with the mid-year report. However, extensive data analyses are not provided in this report.

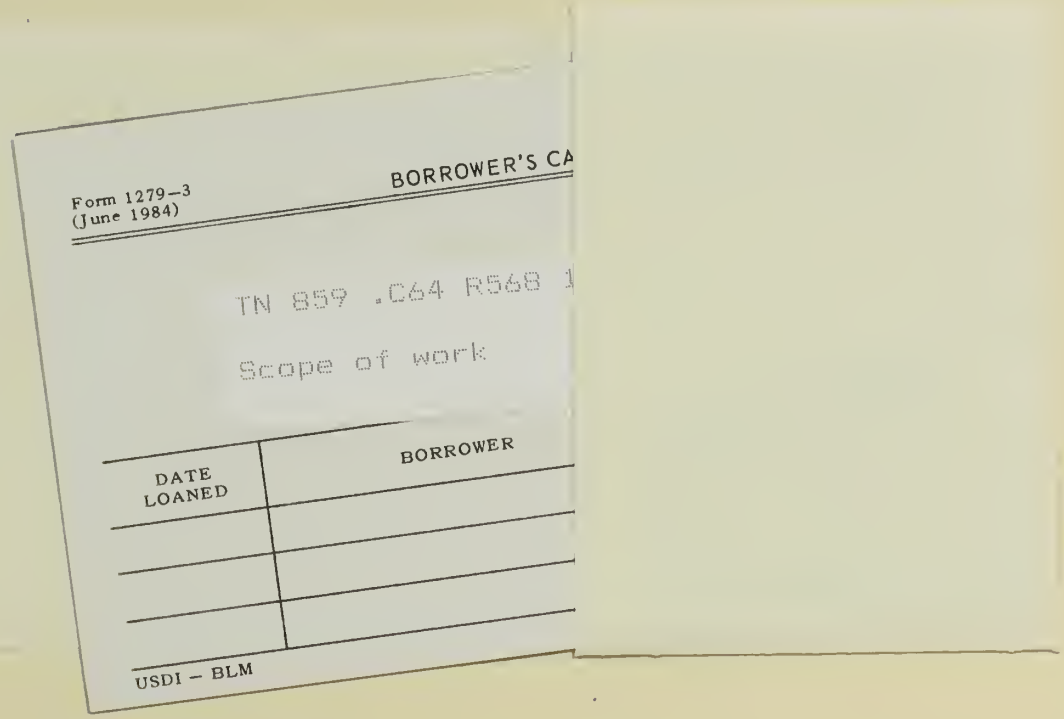
The year-end data report is submitted to the OSO on April 30th (or nearest work day following the 30th) of each monitoring program year. Year-end reports contain raw and reduced data for the previous calendar year, yearly summaries, analyses and interpretations of the 12-month data set, and, where appropriate, comparisons between years, seasons, and other data sets. The year-end report is designed to report on the program specific data base for the tract and vicinity. Trends are identified, anomalies are flagged, and long term evaluations are made. Development-linked perturbations are identified and assessed as to significance.

Reports for the Modular Development Phase (MDP) are entitled "Monitoring Reports" and are numbered sequentially dating from the initiation of the MDP monitoring program in 1977 (Table 6-1). This program will be continued until it becomes necessary to modify it for the commercial phase or it is discontinued by order of the OSO according to terms of the lease.

Table 6-1. RBOSC MDP Environmental Monitoring Program Report Schedule

Report	Data Collection Period[1]	Report Submittal Date
Monitoring Report 1	Sep. 1977 - Nov. 1977	Feb. 28, 1978
Monitoring Report 2	Dec. 1977 - May 1978	Aug. 31, 1978
Monitoring Report 3	Dec. 1977 - Nov. 1978	Mar. 31, 1979
Monitoring Report 4	Dec. 1978 - May 1979	Aug. 31, 1979
Monitoring Report 5	Dec. 1978 - Nov. 1979	Mar. 31, 1980
Monitoring Report 6	Dec. 1979 - May 1980	Aug. 31, 1980
Monitoring Report 7	Dec. 1979 - Nov. 1980	Mar. 31, 1981
Monitoring Report 8	Dec. 1980 - May 1981	Aug. 31, 1981
Monitoring Report 9	Dec. 1980 - Dec. 1981	Apr. 30, 1982
Monitoring Report 10	Jan. 1982 - June 1982	Sep. 30, 1982
Monitoring Report 11	Jan. 1982 - Dec. 1982	Apr. 30, 1983
Monitoring Report 12	Jan. 1983 - June 1983	Sep. 30, 1983
Monitoring Report 13	Jan. 1983 - Dec. 1983	Apr. 30, 1984
Monitoring Report 14	Jan. 1984 - June 1984	Sep. 30, 1984
Monitoring Report 15	Jan. 1984 - Dec. 1984	Apr. 30, 1985
Monitoring Report 16	Jan. 1985 - June 1985	Sep. 30, 1985
Monitoring Report 17	Jan. 1985 - Dec. 1985	Apr. 30, 1986

[1] Data not received during the reporting period will be reported in the report for the period following receipt.



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